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Preliminary Results of the Nationwide Urban Runoff Program. Volume I

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PRELIMINARY RESULTS
OF THE
NATIONWIDE URBAN RUNOFF PROGRAM

VOLUME I

Water Planning Division
U.S. Environmental Protection Agency
Washington, D.C. 20460

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The possible deleterious water quality effects of non-point sources in general, and urban runoff in particular, were recognized by the Water Pollution Control Act Amendments of 1972. Because of uncertainties about the true significance of urban runoff as a contributor to receiving water quality problems, Congress made treatment of separate stormwater discharges ineligible for Federal funding when it enacted the Clean Water Act in 1977. To obtain information that would help resolve these uncertainties, the Agency established the Nationwide Urban Runoff Program in 1978. This five-year program is intended to answer questions such as: To what extent is urban runoff a contributor to water quality problems across the nation. What is the effectiveness of controls short of treatment in reducing water quality problems where they exist. Are best management practices for control of urban runoff cost effective in comparison to alternative options.

KEYWORDS: *Runoff, *Water pollution, *Urban areas, *Storm water runoff.

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March 1, 1982

VOLUME I

WATER PLANNING DIVISION
U.S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

DISCLAIMER

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FOREWORD

The U.S. Environmental Protection Agency was created because of increasing public and government concern about environmental quality. The complexity of our environment and the interplay among its components require concentrated and integrated approaches to pollution problems.

The possible deleterious water quality effects of non-point sources in general, and urban runoff in particular, were recognized by the Water Pollution Control Act Amendments of 1972. Because of uncertainties about the true significance of urban runoff as a contributor to receiving water quality problems, Congress made treatment of separate stormwater discharges ineligible for Federal funding when it enacted the Clean Water Act in 1977. To obtain information that would help resolve these uncertainties, the Agency established the Nationwide Urban Runoff Program in 1978. This five-year program is intended to answer questions such as:

- To what extent is urban runoff a contributor to water quality problems across the nation?
- What is the effectiveness of controls short of treatment in reducing water quality problems where they exist?
- Are best management practices for control of urban runoff cost effective in comparison to alternative options?

This is an interim report that presents preliminary findings of NURP. A final NURP report will be published in 1983.

PREFACE

A first draft of the preliminary findings of the Nationwide Urban Runoff Program was issued on 30 September 1981. This was done to allow ample time for Agency review, to provide a first indication of content and tone and, most importantly, to allow each of the 28 individual NURP projects time to provide meaningful and substantive comments that could be incorporated in the final version of the preliminary report. To facilitate this project comment process, a meeting with representatives of each project, the EPA Regional offices, and EPA Headquarters' staff was held in mid-October. By issuing the first draft prior to that time, each project was able to fully participate in the October discussion of early NURP findings. Comments were accepted until November 20, 1981 and those received were incorporated as deemed appropriate in a final draft which was issued for review on January 11, 1982. In addition to Agency and project personnel, reviews were solicited from all states, and comments were accepted until February 15, 1982. Those received were harmonized and incorporated in this report.

The early issuance of this report has attendant limitations, however, and it is extremely important that each reader have a full appreciation of them. First and foremost is the fact that the ultimate data base envisioned for the NURP Program is incomplete at this time. For example, many projects have not yet submitted their fixed-site data, and water quality data sets for many storm events are either incomplete (e.g., flow data are not yet available) or missing (not many are available on events that occurred after 1980). Furthermore, some projects have not yet entered their data into EPA's STORET system which NURP uses for data management and analysis.

Secondly, not all of the grantees were at the same place in problem assessment and analysis prior to joining NURP, and not all NURP grants were awarded at the same time. The result of this is that, while a few of the NURP projects are nearly completed or have finished, most are still actively engaged in their planned efforts, and some have only recently begun. Therefore, the broad data base which will eventually result from NURP's wide coverage of geographic regions, hydrological and meteorological conditions, land uses, etc., does not exist at this time.

Thirdly, the experimental designs used by some NURP projects employed a longitudinal approach. For example, some basins were operated without controls for an initial period of time (often a year or more), then provided with controls and monitored so that the "before and after" results can be compared to evaluate control effectiveness. As a result, much of the data available now are for the "uncontrolled" period, with insufficient data on the "controlled" period. This precludes the evaluation of controls on many projects at this time.

As a result of the foregoing, this report must be read with considerable caution. To augment the limited quantity of accessible data in the STORET System, a small pilot data set was assembled to act as a surrogate to allow NURP to explain what will be in the final report. These so-called fast track data were provided by selected individual project personnel (often by telephone) who frequently indicated that the data were tentative and subject to revision. Therefore, the analysis and interpretation of results from the pilot data set must have the same caveat and should be considered primarily as illustration of technique rather than absolute fact.

In conclusion, the final NURP report will be structured around an approach that uses statistical analyses to generalize the data and specific case studies to verify the generalizations and allow them to be focused on various real-world situations. Obviously, given the state of the various NURP projects at this time, no such completed case studies could be included in this preliminary report. However, a few NURP projects have provided initial summaries indicating such tentative findings as can be made at this time.

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This report has been written by members of the EPA NURP Headquarters staff and its consulting team. The principal writers were Dennis N. Athayde and Carl F. Myers (EPA), Philip E. Shelley (EG&G), Eugene D. Driscoll (E. D. Driscoll & Associates), John L. Mancini (Mancini and Di Toro Consultants) and Gail B. Boyd and David Gaboury (Woodward-Clyde Consultants). Material on the analysis of control effectiveness presented in Appendix C was provided by James P. Heaney and Wayne C. Huber. The project descriptions in Appendix G were prepared by the responsible EPA Headquarters Project Officers; Patrice M. Bubar, Norman A. Whalen, Stuart S. Tuller, and Phillip H. Graham. Appendix G was written by Richard Field (Storm and Combined Sewer Section, EPA Office of Research and Development).

The writers gratefully acknowledge the staffs of their respective organizations for their support and contributions to this report and the data analysis presented herein. In this latter regard, special thanks are due to William T. Wells, William F. Eddy, Tommy L. Jones, and Diane M. Sevitski (EG&G).

Gratitude must be expressed to all the reviewers of the earlier drafts of this report. Although too numerous to mention by name, their comments helped strengthen the report.

Lastly, and most importantly, the writers must express their appreciation to EPA Regional and NURP project personnel, in particular those who redoubled their efforts or interrupted busy schedules to especially provide the data used in this report, and without whose support and assistance the NURP Program would be meaningless.

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CHAPTER 1
INTRODUCTION

Rain falling on an urban area results in both benefits and problems. The benefits range from vegetation watering to area cleansing. The problems are associated with urban runoff, that portion of rainfall which drains from the urban surface area and, via natural or man-made drainage systems, into receiving waters.

The historical concern with urban runoff has been with adequate drainage, i.e., prevention of localized flooding. Urban development reduces the pervious land surface area and increases the impervious area, such as roof tops, streets, and sidewalks, where water cannot infiltrate. Thus, in comparison with an undeveloped area for a given storm event, an urban area will have more runoff that will occur more quickly. The substantial increases in the rate of flow and total volume have a decided effect on erosion rates and flooding. It is not surprising, therefore, that at the local level the principal concern with urban runoff is quantity.

It is only recently that concern with urban runoff as a contributor to receiving water quality problems has been expressed. Section 62 of the Water Quality Act of 1965 (P.L. 89-234) authorized the Federal government to make grants for the purpose of "assisting in the development of any project which will demonstrate a new or improved method of controlling the discharge into any water of untreated or inadequately treated sewage or other waste from sewerage which carry storm water or both storm water and sewage or other waste ..." The Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500) signaled a heightened national awareness of the degraded state of the nation's surface waters and a Congressional intent that national water quality goals be pursued. The scarcely two-year old Environmental Protection Agency, building upon its predecessors' activities, took up the challenge and began to implement this far reaching legislation.

Section 208 of The Act resulted in the designation of State and local water quality management agencies to integrate water quality activities. As point source discharges were increasingly brought under control and funds for the construction and upgrading of municipal sewage treatment plants were granted, the awareness of nonpoint sources, including urban runoff and combined sewer overflows, as potential contributors to water quality degradation was heightened. Uncertainties associated with the local nature and extent of urban runoff water quality problems, the effectiveness of possible management and control measures, and their affordability in terms of benefits to be derived mounted as water quality management plans were developed. The unknowns were so great and certain control cost estimates were so high that when Congress, as a result of careful review of progress to date, passed the Clean Water Act of 1977 (P.L. 95-217), it deleted Federal funding for the treatment of separate stormwater discharges. There was simply not enough known about urban runoff loads, impacts, and controls.

In 1978, after reviewing the past work on urban runoff of the Areawide Agencies, EPA determined that additional, consistent data were needed. In response EPA initiated its Nationwide Urban Runoff Program (NURP) to build upon pertinent prior work and to provide additional practical information and insights to guide future policy and program development and implementation. This program includes twenty-eight planning efforts focused on urban stormwater and water quality. While these projects are separate and distinct, most share certain commonalities. All are involved with one or more of the following elements: characterizing pollutant types, loads, and effects on receiving water quality; determining the need for control; and evaluating various alternatives for the control of stormwater pollution.

NURP data are being taken and used in a planning context. Guidance was provided to allow comparison of results from all projects. Methods common to all projects were used to enable one to distinguish between the characteristics of the cities and not be misled because the data were obtained in 28 different ways.

The NURP is not a research program, in that it is not set up as a scientific study, but rather it is a practical (engineering) approach to provide information sufficient to allow planning decisions to be made. NURP's basic objective is to provide information to make the best possible policy decisions on Federal, State, and local involvement with urban stormwater runoff and its control.

CHAPTER 2
BACKGROUND

EARLY PERCEPTIONS

As noted earlier, drainage is perhaps the single most important factor of the urban hydrological cycle. Nuisance flooding, more than anything else, will give Public Works directors concern as complaints are received from unhappy motorists and home owners about flooded intersections and inundated basements. This type of flooding has always been a concern of city engineers and administrators.

As cities grow, the land surface becomes more impervious as development occurs. The increased impervious area results in increased runoff rates and volumes. Generally, downstream conveyance systems were not designed for the increased runoff from upstream development, resulting in nuisance flooding in older sections of town. This has been occurring across the United States for many years. Drainage has always been considered a local responsibility, usually of the City or County Public Works Department. Rarely does this responsibility go to the State or Federal level. One exception is catastrophic flooding involving human life and extensive property damage.

The U.S. Public Health Service as early as 1964 had identified pollutants in urban runoff and concluded that there may be water quality problems associated with stormwater runoff (USPHS, 1964). In 1968, the Urban Water Resources Research Committee of the American Society of Civil Engineers (ASCE), directed by M. B. McPherson and sponsored by the U.S. Geological Survey, recognized the potential threat of pollution from urban runoff and identified a research program to obtain needed information to characterize urban stormwater quality (ASCE, 1968).

In the late 1960's, the Federal Water Quality Administration (FWQA) performed a study, "Stormwater Pollution from Urban Land Activity", in Tulsa, Oklahoma, in an area served by separate storm sewers (FWQA, 1970). This first attempt at using regression analysis on urban runoff indicated that stormwater runoff quantity provides very poor correlations with water quality constituents except for suspended solids. Comparing the concentrations of various pollutants examined by this study (separate storm sewers) with previous combined sewer overflow data indicated that separate storm runoff contained much lower values for BOD, fecal coliform, and most other pollutant concentrations. The study concluded that the largest portion of pollutants resulted from washoff of material from impervious surfaces and the erosion of drainage channels caused by high volumes of runoff developed on the impervious surfaces. Control of urban runoff was recommended to reduce both total runoff volume and rates.

Atlanta, Georgia is an example of a city that has both a combined sewer system and a separate system. In 1971, the U.S. Environmental Protection

Agency performed a study entitled "Storm and Combined Sewer Pollution Source and Abatement" (USEPA, 1971), which compared the contribution of various sources of pollutant discharge. This study concluded that, on an annual basis, 64 percent of the BOD load came from separate storm sewers and 19 percent came from combined sewers, the balance (17 percent) coming from treatment plants.

"Storm Water Problems and Control in Sanitary Sewers" (USEPA, 1971) was performed in Oakland and Berkeley, California. This study was concerned with the infiltration of stormwater into sanitary sewers. While only four percent of the East Bay area is combined sewerage and the remaining 96 percent separate, it is clear from the report that infiltration can cause a separate system to function as though it were combined.

Sacramento, California is similar to Atlanta in that both have systems with combined and separate storm sewers. Where they differ is the poorer quality of stormwater found in Sacramento; so poor in fact, that it rivals the average strength of domestic wastewater. However, the concentrations for BOD are so unrealistically high, that contamination of the runoff by raw sanitary sewage must be considered as a possibility.

In 1973, the Council on Environmental Quality published a report entitled, "Total Urban Pollutant Loads: Sources and Abatement Strategies" (CEQ, 1973). The primary conclusion was that much pollution was coming from urban runoff and that, unless it was taken care of, the goals of the Act would not be met. The CEQ report was based almost entirely on the aforementioned FWQA and USEPA studies.

It should be noted that all of the above mentioned work was done by EPA's Office of Research and Development Program for Storm and Combined Sewers.

CONCLUSIONS FROM SECTION 208 EFFORTS

According to USEPA guidance, there were 17 topic areas including urban runoff that were to be addressed by all Water Quality Management (WQM) agencies in developing their 208-funded plans. Although all topic areas were to be covered, the degree of emphasis was left to the individual designated agency. As a result, the amount of the 208 grant funding that was spent in the area of urban runoff varied greatly, but was rarely a major portion.

Many of the "208" studies began with the assumption that urban runoff was an important cause of water quality problems. Although the studies progressed and much information on runoff and receiving waters was developed, it was still difficult to assess urban runoff's role as a major cause of problems. This was partly because of interferences by other sources and complex relationships within the receiving waters. It was also due to the difficulties in deciding what constitutes a "problem". In some cases, "problems" were synonymous with criteria violations; in others, "problems" were synonymous with an impairment or denial of beneficial uses. In many cases, "problems" were concluded to exist or be likely to exist, simply on the basis of possible contaminant presence in urban runoff as determined from values taken from literature on prior studies conducted elsewhere. The practical implication of these differences of opinion was that local agencies were very reluctant to make commitments to implementing urban runoff controls in the absence of a clear problem definition.

Furthermore, in the early years of the 208 program guidance was vague on how to address urban runoff. As a result, local agencies took a wait-and-see attitude on the stormwater portion of their plans. They simply did not know what EPA would eventually do on the issue of stormwater control.

Another major obstacle to implementation was associated with the uncertainty surrounding the effectiveness of controls. Many of the measures proposed for controlling urban runoff are either new or special applications of conventional practices developed for other purposes. Engineers, planners, public works personnel, and other decision makers are understandably reluctant to invest large amounts of time and money in controls which may not perform as hoped.

Other obstacles to implementation included basic data deficiencies on sources, transport mechanisms, and receiving water characteristics (hydrologic and water quality aspects). Some of the more important topic areas where knowledge is lacking as identified in an earlier review of the subject (Shelley and Driscoll, 1980) are summarized below:

- Sources -- not enough is known about where pollutants originate. Major sources certainly include vehicles, vegetation, erosion, fertilizer and pesticide application, litter, animals, and air pollution. A better understanding of source contributions could enhance control opportunities.

- Washoff/transport mechanisms -- not enough is known about how pollutants get from the sources to the receiving waters. Models for simulating runoff would be more useful in problem definition and control evaluation if they could accurately reflect washoff and transport mechanisms.

- Impacts -- it is still difficult to go beyond speculation in assigning urban runoff its proper share of responsibility for pollution problems where other sources also contribute. In cases where other sources create obvious problems, it is difficult to determine the appropriate level of control for urban runoff.

- Relative benefits -- local planners have difficulty deciding whether the various benefits of controlling urban runoff quality justify the costs involved. There is considerable controversy over the present dry weather standards' relationship to beneficial uses, given the time and space scales of storm events and their intermittent nature. Many plans fail to be implemented because of uncertainties regarding: How much control is enough? Who benefits? Who should pay? Who should decide?

- Controls -- some of the control measures cited in typical "208" plans are plausible candidates, but their application for the purpose of urban runoff pollution control has not been studied quantitatively. Both cost and effectiveness data on full-scale programs are lacking.

ORD EFFORT

For the past 15 years, EPA's Office of Research and Development (ORD) has conducted over 250 studies on the characterization and control of stormwater discharge and combined sewer overflow (CSOs), with particular emphasis on the latter due to its greater pollution potential. Following Agency guidance, ORD has not emphasized studies on receiving water impacts and effects, although it has done work in this area. Because it is nearly impossible to segregate benefits and strategies of urban stormwater runoff pollution control from drainage, flood, and erosion control, multipurpose analysis and control have been stressed. Many significant results have been obtained by this ORD effort, and it has dramatically increased the technical literature in the area.

Data from ORD studies have indicated the high variability of concentrations in urban runoff and, based on loading projections, have suggested that urban stormwater can be a significant contribution to the receiving water, being on the order of secondary treatment plant effluent for some constituents. ORD efforts to find direct urban runoff generated receiving water impacts using the conventional dissolved oxygen parameter have been only partly successful. However, this was only one study and should not be interpreted as the final word. Nonetheless, based on the size of the load coming from urban runoff, a significant pollution potential is there for at least some types of receiving waters. For example, a small urban lake, at least in some parts of the country, could receive nutrient loads sufficient to increase algal productivity and accelerate the eutrophication process. The existence of heavy metals and certain organics (mostly of petroleum origin) in urban runoff has also been documented by the ORD program.

In addition to studying urban runoff loads, the ORD program has investigated a number of management and control alternatives that could be used to reduce these loads where they were found to create water quality problems severe enough to warrant action. This portion of the effort has been very successful, and many innovative techniques have been proposed and tested. As a result of such demonstrations, state-of-the-art reports have been prepared to document many of these developments, thereby allowing the technology to be utilized in other locations as well. Included have been such control measures as on-site (upstream) storage; porous pavement; the swirl concentrator, helical bend, tube settler, and fine mesh screens for grit and settleable solids removal; street sweeping; disinfection; high rate filtration, dissolved air flotation, micro-screening for SS/BOD removal; and others. Although many of these control options were developed with CSO control in mind, some may have application in urban runoff control also, once their effectiveness has been conclusively demonstrated and initial and operating cost data are available to allow the necessary trade-off studies to be made in order to permit responsible decision-making.

The ORD program formed an invaluable source of data and information that was used to design and guide the program and, without the prior and ongoing ORD support, the task of NURP would have been much more difficult. Also, three NURP projects are joint efforts with ORD. These are West Roxbury, Mass, Bellevue, Washington, and Lansing, Michigan. For a full discussion of the ORD effort and references to its many significant results, see Appendix H.

OTHER PRIOR/ONGOING EFFORTS

Needs Surveys.

The Act requires EPA to provide Congress every two years with a needs assessment in the six categories of the construction grant funds program necessary to meet the goals of the Act. In 1974, the Needs Survey for Category VI, Separate Storm Sewer Discharges, was done by each State. Using the goals of the Act as the criteria to be met, they identified a cost of about $235 billion (June 1973 dollars). One State alone identified $80 billion in needs to control separate storm sewer discharges. In 1976, the Needs Survey was conducted by the Agency, and it was found that Category VI funding of $66 billion would be required to meet the goals of the Act. This survey broke the goals into three categories or levels of pollution abatement; (1) Aesthetics, (2) Fish and Wildlife, and (3) Recreation. Costs to meet each category were determined.

Professional Societies.

In 1968 the ASCE, with funding by the U.S. Geological Survey, had developed the outline for a program to identify the cause and effect of urban stormwater pollution. The recommendations were not followed, and in 1974 at the Rindge, New Hampshire Engineering Foundation Conference jointly sponsored by the ASCE Urban Water Resources Research Council, a similar program was again recommended (EFC/ASCE, 1974). A similar scenario occurred at the Easton, Maryland Conference of 1976 sponsored by the same group. This latter meeting produced a document entitled, "Guide for Collection, Analysis, and Use of Urban Stormwater Data," (EFC/ASCE, 1976).

DISCUSSION

In the past (ca 1890), dilution was considered to be the appropriate way to control combined sewer overflows, since the primary concern was odor and related nuisances. Between 1890 and 1960 little concern was shown for stormwater pollution. Stormwater problems were primarily related to concerns about drainage. As time progressed, water quality was considered and characterized as concentrations of certain pollutants and loads of these pollutants. In the 70's, problems were defined in terms of pounds of pollutants needing to be removed. The attitude was one of preventing pollution.

Past work, reported by the Agency and published in professional journals, has focused on the type and amount of pollutants and the methods to reduce the loads. None of the reports or articles considered and reported on the improvement or the need to improve quality of the receiving water body associated with the study.

A conclusion common to all reports was that not enough was known about stormwater to completely understand its cause and effect. Also common to all reports was the recommendation that further study and more data were needed. The ultimate proof of the lack of belief and uncertainties in this area lies in the fact that implementation of stormwater controls for water quality has been virtually absent throughout the nation. Thus, there is a critical need to objectively examine the situation.

There are many factors that led to the development of NURP. Necessity was the primary factor. As implementation of P.L. 92-500 moved into full swing, it was becoming apparent that we were not making much progress in the area of urban runoff. In 1974 the Agency lost a court decision that, in essence, required it to issue permits for separate storm sewer discharges. On appeal in 1977 the court decision was upheld. It was in 1976 when the Agency requested that the Areawide Waste Management Planning Program focus on the three or four most important elements of the 17 items required by the regulations.

Two years later EPA reviewed the 93 "208" Areawide Agency's work plans that had identified urban runoff as one element upon which they would focus. The results, in regard to furthering our understanding of the pollution aspects of urban runoff, were disappointing. If one reason can be identified, it was the lack of data.

As mentioned earlier, the Rindge Conference, as one of its recommendations, outlined a program to obtain the data necessary to provide a good understanding of stormwater pollution (EFC/ASCE, 1974). It is not coincidental that the NURP program is quite similar in design to those recommendations.

THE NATIONWIDE URBAN RUNOFF PROGRAM

PROGRAM DESIGN

It must be understood from the beginning that NURP is not a research program, and it is not designed as such. The program itself is a support function. It provides direction and assistance to 28 separate and distinct planning projects. NURP acts as a clearinghouse and in that capacity provides a common communication link to and among all 28 projects.

The NURP effort is directed towards first reviewing what is known about urban runoff mechanisms, problems, and controls and then building upon this base. The overall objective of the program is to provide credible information on which to base decisions. In light of court decisions, needs survey costs, the questions the 95th Congress appeared to raise in revising the Act, and based upon what was known, it is clear that more information is needed.

The Nationwide Urban Runoff Program involved identifying a limited number of locations for intensive data gathering and study with the purpose of:

1. Meeting program objectives,
2. Developing implementation plans for those areas, and
3. Demonstrating transferability, so that solutions and knowledge gained can be applied in other areas (without the need for intensive data gathering efforts).

The design provides a full range of technical and management assistance to each project as the needs arise. The forum for the communication of experience, sharing of data, and transfer of lessons learned is provided through semi-annual meetings of all projects. Under the strategy, the roles and responsibilities of all involved participants were clearly defined and communicated at the outset. These were reviewed and revised where warranted as the projects progressed.

The design recognizes the need for program coordination, both within and outside of the Agency, to maximize the use of limited resources and minimize conflict and overlap.

The 28 NURP projects are being managed by either State, county, city, or regional governmental associations. In addition to EPA, the U.S. Geological Survey is involved as a cooperator through an inter-agency agreement with eleven NURP projects. This involvement includes funding support and typically is in the form of data collection and analysis and, in some projects, the evaluation of controls. The Tennessee Valley Authority is involved in one project, and they too are providing data collection, analysis, and evaluation of controls.

As a major objective of the program is the acquisition of data, it is imperative that the approach recognize the inherent pitfalls of a data gathering program. Since the data are to be used to characterize problems, evaluate receiving water impacts from urban runoff, and evaluate management practices, consistent methods of data collection would need to be developed and adopted.

Selection.
Projects were selected from the original 93 Areawide Agencies that had identified urban runoff as one of their significant problems. The intention was to build upon what had already been done. Also, projects that would be a part of this program needed to provide a range of certain characteristics, e.g., hydrologic regimes, land uses, populations, drainage systems, etc. Actual selection of projects was a joint effort between the States, local government, and Regional EPA offices. The actual selection criteria used to screen the 93 agencies were as follows:

1. Problem identified. Had a problem been identified? Could that problem be directly related to separate storm sewer discharges? What pollutant or pollutants were causing the problem? And, using NURP identification categories, was the "problem";

    I. denying beneficial use,

    II. violating a State water quality criterion, or

    III. public concern?

2. Type of Receiving Water. Effects of stormwater runoff in the receiving water are our ultimate concern. Flowing streams, tidal rivers, estuaries, oceans, impoundments, and lakes have different hydrologic and water quality responses. Proposed project receiving water, therefore, had to be examined to ensure that a proper mix was included in the overall program.

3. Hydrologic Characteristics. Rainfall occurrence is perhaps the single most important factor in studying urban runoff phenomena as it provides the means of conveyance of pollutants from their source to the receiving water. Locations in different hydrologic regimes were chosen for the projects.

4. Urban Characteristics. Population density, age of community, land use, etc. must be taken into account as possible indicators of the waste loads and ultimately the rainfall-runoff water quality relationship. Sewerage system is another factor to consider; whether it is combined, or separate, or mixed, and how severe the infiltration and inflow problems may be. These will have different effects on the quantity and quality of storm runoff, and were balanced as well as possible in project selection.

5. Beneficial Use of Receiving Water. This factor greatly affects the type of control measure desired. An attempt was made to include a wide range in project selection.

These were the primary criteria used to identify potential projects. Other factors, of course, had to be considered. Among these are willingness to participate, acceptance of the project by the State, experience of project teams, and so forth. Since these were not research grants, but planning grants, a major consideration was working relationships with other, local public agencies and the ability to raise local matching funds.

Program Assistance

Technical expertise and resources available for urban runoff planning projects varied among the various program participants across the nation. Therefore, NURP strategy called for providing a full range of technical assistance to each project as needed and for intercommunication of experience, sharing of data, and transfer of lessons learned on a timely basis.

Assistance was provided in the development of the final work plans. It was important to ensure that there be comparability of methods, especially in the collection of data. If there was to be any difference in the data from city to city, it must be due to the characteristics of each city and not in how the data were taken.

Instrumentation was another area where assistance was provided, here in the form of information on available equipment, installation, calibration, etc. One of the more important elements of a data collection program is the "goodness" or quality of the data themselves. Questionable data would be of little use. In that regard, it was emphasized at the outset that a quality assurance and quality control element was required of each project.

Periodic visits to each project were part of the approach to ensure that each project be provided the opportunity to discuss any problems, whether technical or administrative. The visiting team typically included a regional representative, headquarters representative, and one or two highly trained and experienced consultants. All interested parties, including representatives from State or local governments, were requested to attend those visits.

As the projects moved farther into their planned activities, the time for analysis of data approached. Each project, as part of their original workplan development was required to identify how they were going to analyze their data. No single method was recommended for each project. It was believed that most available methods were suitable if used properly. Guidance on proper use was provided as a part of technical assistance through project visits and special workshops for this purpose.

Communication

It has been the intention of NURP that the entire group of program participants function as a single team. To aid in ensuring that this occurred, a communication program was developed. So that the individual project directors would have an opportunity to discuss their projects freely among themselves, national meetings were conducted semi-annually.

Reports are required of each project quarterly. Headquarters also provides a quarterly report on all projects summarizing the status of each and providing discussions of problems encountered and solutions found.

CHAPTER 3
URBAN RUNOFF PERSPECTIVES

In evaluating the impacts of urban runoff, a number of perspectives must be well understood. The following summarizes such perspectives.

WATER QUANTITY CONCERNS

Flooding

Historically, as noted earlier, drainage has been the principal local urban runoff concern. Such water quantity concerns can be divided into two basic categories: nuisance flooding; and major, sometimes catastrophic, flooding. Nuisance flooding, e.g., temporary ponding of water on streets, short-term road closings, minor basement flooding, etc. although possibly intolerable to those immediately affected, rarely affects the entire urban population. Nonetheless, the concerns of the (often vocal) minority of affected citizens typically reaches the point where local action is taken to prevent or minimize the occurrence of such events. It must be stressed that such mitigation activities are usually locally determined, funded, and implemented because both the public at large and local government agree that such flooding constitutes a problem.

A catastrophic flood event, on the other hand, typically affects the majority of the urban populace. Mitigation measures often involve major costs beyond the local ability to pay and usually involve areas extending well beyond local jurisdictions. Historically, the Federal government has become involved, through a number of related efforts, in major flood control. Water quantity problems are relatively easy to define. The extent of flooding is readily observable, the degree of damage is easily determined, and the benefits of a flood control project can be estimated. Thus, decision makers face a relatively low risk in determining appropriate courses of action and justifying the associated costs in light of benefits.

Erosion and Sedimentation

Erosion is a natural process resulting from rainfall and runoff wherein soil and other particles are loosened from the land surface and transported into conveyance systems and natural water bodies. Since land surface erosion represents the principle source of sediment, soil type and land cover are major factors in determining the severity and extent of sedimentation problems. Although erosion is a natural process, it is frequently exacerbated by the activities of man, both urban and rural.

When addressing the broad spectrum of problems found in receiving streams as a result of sedimentation, it is convenient to divide them into two categories; (1) those such as stream bank erosion that often respond to control measures directed at nuisance flood prevention, and (2) those that are not controlled by such projects. When sediment loads are discharged into and transported by receiving streams, the effects are primarily physical and only secondarily chemical, as relatively benign mineral constituents make up the primary sediment load. An exception to this would be naturally occuring nutrients. Among the physical problems imposed upon the receiving waters are excess turbidity reducing light penetration and, thereby, interfering with sight feeding and photosynthesis; gill and filter clogging in aquatic organisms and resulting, for example, in retarded growth, systemic disfunction, or asphyxiation in extreme cases; and benthal deposition which can bury bottom dwelling organisms, reduce habitat for juveniles, and interfere with egg deposition and hatching.

Although sedimentation is a storm-event related problem, it is not exclusively either a quantity of flow problem or a water quality problem. Thus, as a hybrid problem, sedimentation control has received a mixed approach. Involved organizations range from Federal agencies such as the Army Corps of Engineers and the Soil Conservation Service, to local drainage and sedimentation control officials, with frequent involvement from State and county governmental agencies.

Urbanization

Urbanization accelerates erosion through alteration of the land surface due to development. Disturbing the land cover, altering natural drainage patterns, and increasing impervious area increases the quantity and velocity of runoff, thereby increasing erosion potential as well as flooding possibilities. Also, sedimentation products which result from urban activities are not as relatively benign as natural mineral products. Atmospheric deposition associated with industrial, energy, and agricultural production activities, and added surface particulates resulting from tire wear, auto exhaust, road surface decomposition, etc., fall in this latter category. Their effects on the receiving water tend to be more chemical than physical. They may contain toxic substances (e.g. heavy metals) and/or other compounds which can have a negative impact upon the receiving water and the ecological community that it supports.

WATER QUALITY CONCERNS

As indicated in the introduction, the notion that urban runoff can be a significant contributor to the impairment or degradation of the quality of receiving waters has been formed only recently and is not universally shared. It is the totality of receiving water characteristics (flow rate, size or volume, and physical and chemical characteristics) that will affect its use. First and foremost, there must be present an appropriate rate of flow and/or volume in the receiving water to support the desired use. For example, one cannot consider swimming in a stream that in only one foot deep, nor can one realistically expect to water ski on a small pond.

In addressing the water quality that will support a designated use, specific characteristics can be associated with specific uses. For example, in the case of swimming, total dissolved solids and dissolved oxygen levels are not especially important, whereas pathogenic bacterial, or viral organisms and turbidity are. For irrigation, the biochemical oxygen demand of the water is of little concern to the farmer, while its total dissolved solids level is of immense concern to minimize salt buildup. Although a high nutrient level is very detrimental to the quality of impounded waters by hastening the eutrophication processes, nutrients may be prized by the farmer in irrigation water.

It is also important to note that it is the level, rather than the mere presence of a water quality constituent, that will affect use. It must be recognized that concentration progression is highly nonlinear with respect to impact upon use, with plateau effects not uncommon. For example, consider dissolved oxygen and its effect upon fin fish. Down to a certain level below saturation there will be virtually no important effect upon a given species. As dissolved oxygen levels fall below this threshold, some more sensitive members of the species will begin to be affected (with death by suffocation the ultimate result), and as levels continue to fall, the affected percentage of the population will increase until, finally, a level is reached at which the entire population can no longer survive. Continued depression of dissolved oxygen levels down to zero will have no further effect upon the community since it no longer exists. It is important to keep this plateau effect in mind when addressing remedial measures to restore beneficial uses, since limited removal of a polluting substance may do nothing to alleviate the problem. In the example given above, if oxygen demanding substance input to the receiving water were to be reduced by a certain control strategy with a given cost, the result might be that the dissolved oxygen level of the receiving water would rise from one to three mg/l. If trout were the fish species involved, they could still not survive, and although polluting substances were removed and money was spent, the desired benefit would not be achieved.

WATER QUANTITY AND QUALITY CONTROL

There is no question that excessive urban runoff causes problems, e.g., nuisance flooding of basements, intersections, etc. Remedial costs may be high, but the benefits are obvious. Currently, there is a growing national awareness that if steps are taken during the planning phase of development, excessive stormwater discharges can be prevented, at least from the smaller, more frequent events. Large infrequent storms will always tend to cause problems.

Past And Current Work.

During the past two decades attention has been focused on prevention of flooding from, and reduction of, runoff rates and volumes. During the early 1970's, a manual of practices was prepared under grants from the Office of Water Research and Technology (OWRT) sponsored by the American Public Works Association (AWPA) stressing detention (Poertner, 1974). It was at this time that the University of Delaware issued a manual of practices on methods to control rates and volumes of urban runoff (Toubier and Westmacott, 1974).

Work done by the ASCE Urban Water Resources Research Council during the sixties stressed the concept of a natural easement of drainage, observing that there were two drainage ways; a major for large events and a minor for smaller more frequent events (Jones, 1968). It was claimed that money could be saved by using natural channels, swales, etc., thus reducing the need for more expensive concrete conveyances.

The idea of natural runoff, green belts, etc., was a new little tried concept. In 1970, EPA's ORD started what is called the Woodlands project in Texas near Houston. The study was to determine how water could be protected or improved by the use of natural drainage ways, detention, porous pavements, increased infiltration rates, and a decrease in runoff rates (Characklis, 1979).

The foregoing is by no means an exhaustive list, but indicates the move toward a better way of taking care of urban drainage.

Federal Involvement.

As part of the national effort to control erosion from agricultural lands, the Soil Conservation Service (SCS) of the United States Department of Agriculture (USDA) was established. One of the functions of the SCS is to provide technical assistance in developing erosion control plans. During the past decade or so, the SCS has become more and more involved with areas other than agricultural, as the methods that they have developed over the past 50 years are applicable most anywhere. It is not surprising then that the SCS is involved in erosion control in urban areas. They have produced a most useful document for assessing urban hydrology in small watersheds (SCS, 1975).

Other Federal agencies that have an interest in urban runoff and its control include the U.S. Geological Survey, the Federal Highway Administration, the Federal Housing Administration, the Tennessee Valley Authority, and there are still others too numerous to mention.

State And Local Involvement.

Although some states have adopted runoff control legislation to protect property, the control of erosion and urban drainage has traditionally been a local matter. Erosion control at the state level was first to become common, and today most states have erosion contol laws in force. Few states had enacted runoff rate/quantity legislation, however. This situation has begun to change over the last decade. Maryland is one example of this trend, with legislation which is implemented at the county level. Montgomery County, Maryland is an excellent example.

The methods used are preventive in nature, and control erosion by design. This type of pollution can be controlled now. We know how to do it. We have the knowledge and experience and have been doing so for some time. Many local agencies are developing control plans along these lines. Baltimore Regional Planning Council is a good example of where an area is moving ahead to control what can and should be controlled. This report will not cover this aspect of control.

PROBLEM DEFINITION

As pointed out earlier, water quantity problems are relatively easy to define. Water quality problems, on the other hand, are more elusive since they involve experimental aspects and expectations of the population. They are not immediately obvious and are usually less dramatic than, for example, floods. They also tend to vary markedly with locality and geographic regions within the country. For example, northwestern residents may want to upgrade stream quality to support a more highly priced species of game fish, while a northeastern resident contemplating the river flowing by his factory might be grateful for any game fish at all. Thus, a methodological approach to the determination of water quality problems is essential if one is to consider the relative role of urban runoff as a contributor. One should avoid the simplistic logic train that says: (a) water quality problems are caused by pollutants, (b) there are pollutants in urban runoff, therefore, (c) urban runoff causes "problems". The unspoken implication is that a "problem" by definition requires action, and any type of "problem" warrants equally vigorous action. It becomes clear that a precise definition of a water quality "problem" from urban runoff is necessary. For this purpose, the Nationwide Urban Runoff Program has adopted a three level definition. The levels are:

I. Impairment or denial of beneficial uses;

II. Water quality criterion violation; and

III. Local public perception.

Impairment or denial of a designated use is the first problem level. Here a determination has been made of a realizable beneficial use, and water quality characteristics are such that attainment of the use cannot be fully realized. The second level of problem definition is a water quality criterion violation. Here some measure or measures of water quality characteristics violate recommended or mandatory levels for the receiving water classification. Some of the subtle distinctions between this and the preceding problem definition arise in the fact that receiving water classification may not be appropriate, the beneficial use may not be impaired or denied, and the water quality criteria associated with that classification may or may not be overly conservative or directly related to the desired use.

The third level of problem definition involves public perception. This may be expressed in a number of ways, such as telephone calls to public officials complaining about receiving water color, odor, or general aesthetic appearance. Public perception of receiving water body problems is highly variable also. Some people enjoy fishing for carp or gar, children will play in almost any creek, and so on. This level of problem definition can also include one concept of anti-degradation. Here the thought is that no polluting substances of any kind in any quantity should be discharged into the receiving water regardless of its natural assimilative capacity. This concern has its ultimate expression in the "zero discharge" concept. EPA's concept of anti-degradation, on the other hand, refers to degradation of use; a subtle but essential difference.

The foregoing levels of problem definition provide an essential framework within which to discuss water quality problems associated with urban runoff. However, it is important to understand that when one is dealing at a local level all three elements are typically present. Thus, it is up to the local decision makers, influenced by other levels of support and concern, to carefully weigh each prior to making a final decision about the existence and extent of a problem and how it is to be defined. It follows that, if this step of problem definition is done carelessly, it will be difficult to plan an effective control strategy and establish a means for assessing its effectiveness.

CHAPTER 4
METHODS OF ANALYSIS

INTRODUCTION

This chapter identifies and describes the methods used to analyze the data developed by the NURP program. The descriptions provided here are general; where a procedure which was used requires a more detailed explanation, it is provided in Appendix C.

The procedures described in this chapter are those used to address the need to generalize about the aspects of interest for a national determination. In some cases, similar or equivalent procedures were applied at the individual project level; in other cases, methods adopted by individual projects to respond to local needs and interests are different. Where possible, we have compared either detailed results, or conclusions drawn from the interpretation of such results, as derived from both local and national approaches.

By and large, the methodologies that were selected were developed under different EPA efforts, many under the sponsorship of the Office of Research and Development.

This chapter is structured such that it addresses, in sequence (1) the characterization of urban runoff contaminant loads; (2) water quality effects of such loads, including their impact on beneficial uses of the receiving water bodies; and (3) the effect of control measures, including both technical effectiveness in terms of ability to reduce pollutant loads, and cost characteristics.

The Data Management Procedures Manual, one of the project documents developed under the NURP project is an additional source of information on details of analysis methods utilized in the project.

URBAN RUNOFF POLLUTANT LOADS

General.

A substantial component of the individual NURP projects was the acquisition of a data base for a number of storm events, consisting of precipitation and the resulting quantity and quality of runoff from a number of local urban catchments. The principal EPA objective in the analysis of these data has been to develop a concise summary of the characteristics of urban runoff, and to examine any similarities or differences in a way which would make possible reliable quantitative statements concerning "transferability" of such data. The term is used to represent the ability to make sufficiently accurate estimates of urban runoff loads of pertinent pollutants at locations where an adequate monitoring program can not be performed because of time, budget or other constraints, by utilizing the national data base, and pertinent local precipitation and land use characteristics.

This is a particularly important objective, because of the combination of wide spatial distribution of urban runoff discharge locations, the intermittent and highly variable nature of the rainfall-runoff process, and the relatively high cost of monitoring programs in general. It is generally accepted, and supported by NURP experience, that limited monitoring programs for storm runoff provide results with relatively low confidence levels in terms of estimates of overall pollutant loads from an area.

The principal thrust has thus been the characterization of conventional pollutants in urban runoff (including a number of the more commonly encountered heavy metals). However, a number of additional factors have also been addressed in the program, and are discussed in this chapter because they relate closely to the general issue of pollutant loads. These include the following:

- Priority Pollutants - a limited monitoring effort was conducted, whose principal objective was to provide information on the presence or absence of compounds on EPA's priority pollutant list in urban runoff.
- Wetfall/Dryfall - as part of program elements designed to examine sources of pollutants in urban runoff, a number of projects operated atmospheric monitoring stations for characterizing pollutant contributions from precipitation (wetfall) and from dry weather deposition (dryfall).
- Soluble vs Particulate - The distribution of soluble and insoluble forms of a pollutant in urban runoff (particularly metals and nutrients) was examined in both the conventional pollutant and priority pollutant aspects of the study, because certain beneficial use effects depend strongly on the form in which the contaminant is present.

Conventional Pollutants.
From prior studies and experience, as well as from the data secured by the NURP projects, urban runoff flows and concentrations are known to be highly variable. Substantial variations occur within a particular event and from one event to the next at a particular site. It is usually difficult to decide, based on superficial examination of urban storm runoff data, how much, if any, of the observed differences in data between two sites reflect real differences due to site characteristics, versus an inherent variability which would be encountered at any site.

For this reason, a statistical approach to the analysis of conventional pollutant data was adopted. Standard statistical procedures (summarized and detailed in Section 1 of Appendix C) were used to define central tendency (a mean or median) and spread (standard deviation or coefficient of variation) of a data set. Pooled data for each pollutant from all monitoring sites was characterized in this way, and the underlying probability distribution was examined and tested. Since the underlying distribution was demonstrated by such tests to be very well represented by a log-normal distribution, the log (base e) transforms of all urban runoff load data were used in developing the statistical characterizations.

The event mean concentration (EMC), defined as the total constituent mass discharge divided by the total runoff volume, was chosen as the primary statistic, and event mean concentrations were calculated for each event at each site in the accessible data base. The rationale for the selection of EMC's for characterizing urban runoff is discussed in a later section. If a flow-weighted composite sample was taken, its concentration was used to represent the event mean concentration. Where sequential discrete samples were taken over the hydrograph, the event mean concentration was determined by calculating the area under the loadograph (the curve of concentration times discharge rate over time) and dividing it by the area under the hydrograph (the curve of runoff volume over time). Details of the calculation procedure have been described in the Data Management Procedures Manual issued by NURP's project team. For the purpose of determining event mean concentrations, rainfall events were defined to be separate precipitation events when there was an intervening time period of at least six hours without rain.

The establishment of the fundamental distribution as log-normal, and the availability of a sufficiently large population of EMC's to provide reliability to the statistics derived, has a number of benefits:

- Concise summaries of highly variable data can be developed.
- Comparisons of results from different sites, events, etc., are convenient and are easily understood.
- Statements can be made concerning frequency of occurrence. One can express how often values will exceed various magnitudes of interest.
- A more useful method of reporting data than the use of ranges is provided; one which is less subject to misinterpretation.
- A framework is provided for examining "transferability" of data in a quantitative manner.

The procedure used to examine transferability of urban runoff loading data is an extension of the foregoing method. Starting with the overall population of pooled data for a pollutant, a series of sub-sets are selected, based on region, land use, season, storm size, etc. (any factor thought to have a significant influence on runoff quality). The data which comprise the selected sub-set are then subjected to a statistical analysis to define mean and variance, and a test of the probability distribution is made. Standard procedures are used (Appendix C) to compare the statistical properties of the sub-set, to determine whether, within prescribed confidence limits, it either does or does not represent a distinct population. A series of iterations of this procedure, using various permutations and combinations of the factors of potential significance, is used to: (a) identify factors which have a significant influence on runoff quality essentially after the inherent variability is filtered out of the comparison, (b) define the relative importance of the factors which prove to be significant, and (c) provide the information for developing quantitative factors (transfer factors) which are used to adjust the national data (i.e., properties of pooled data from all projects) to a specific set of local conditions.

Each of the principal elements of urban runoff relevant to characterizing pollutant loads have been addressed in this manner. These elements include pollutant concentrations (on which the foregoing discussion has been structured), runoff volumes and flow rates, volumetric runoff coefficients (runoff to rainfall ratio) and areal loading rates.

Priority Pollutants.

In cooperation with EPA's Office of Water Regulations and Standards (OWRS), a special study element was built into two-thirds of the NURP projects (19 of 28) to perform a screening to identify which of the compounds on EPA's list of "Priority Pollutants" is found in urban runoff.

Methods utilized in this study element are described in the report which covers this activity, reproduced as Appendix F in this document. Additional analysis performed on priority pollutant data by the NURP project team has been limited to development of a few summary tables and comparisons with results from other activities presented in Chapter 5 of this report.

Wetfall/Dryfall.

(To be defined when data become accessible.)

Soluble vs Particulate Form.

Data on soluble vs particulate forms of certain contaminants have been secured in both the conventional pollutant and priority pollutant program elements. The priority pollutant program additionally determined "Total Recoverable" fractions, corresponding to contaminant forms used in EPA's published toxic criteria guidelines.

Analysis procedures employed to date have been limited to summarizing and comparing results reported in each of these study elements.

Rainfall.

Consistent with the adoption of a storm "event" as the fundamental time scale used in the analysis of data and the interpretation of effects, rainfall data have been analyzed to define "event" statistics for a significant number of locations throughout the country. The method employed for developing the statistical parameters of rainfall intensity, duration, volume, and interval between storm events has been detailed in the "Data Management Procedures Manual" which was prepared as a guidance document for the program.

WATER QUALITY EFFECTS

General.

Characterizing water quality effects resulting from the intermittent pollutant loads introduced into a water body by urban runoff should preferably be done in a way which permits judgments to be made concerning whether such pollutant discharges cause or contribute significantly to a receiving water "problem". To assist in realizing this objective, it is also important to delineate the severity of any indicated problem by quantifying the magnitude, and in the case of intermittent loads, the frequency of occurrence of water quality impacts of significance.

Receiving water impact analyses cannot be readily generalized because there is a high degree of site - specificity to the important factors. The type of beneficial use dictates the pollutants which are of principal concern; the type of water body (stream, lake, estuary) determines how receiving water quality responds to loads, and physical characteristics (size, geometry, flows) have a major influence on the magnitude of response to a particular load.

Those individual NURP projects examining the site-specific impacts of urban runoff on water quality for a variety of beneficial uses and receiving water types are expected to provide important information on the extent to which urban runoff constitutes a "problem" as well as "ground truth" against which more generalized screening techniques can be compared. Methodologies employed in these local studies vary and are described in the individual project reports.

Despite the inherent limitations of a set of generalized receiving water impact analyses, it was considered a necessary element for any appreciation of the general significance of urban runoff in terms of water quality problems, especially adverse effects on beneficial uses. Such procedures provide a means of extrapolating the site-specific conclusions derived from the local NURP studies to some degree.

Accordingly, a set of analysis procedures has been adopted and utilized as screening techniques for characterizing water quality impacts of intermittent urban runoff loads on several classes of water bodies. These procedures are identified and described briefly below: Significant technical aspects are detailed further in appropriate sections of Appendix C.

It has not been possible to perform a "National Assessment" in the usual sense of the term. EPA has determined that it is not realistic (if the basis is effect on beneficial use of a water body) to estimate the total number of water quality problem situations in the nation which result from urban stormwater runoff or the cost of control which would ultimately result. The analysis methods which are available do permit an assessment of a different kind. EPA has applied the analysis procedures as a screening type analysis to define the conditions under which problems of different types are likely or unlikely to occur. From the results of these screening analyses, EPA has drawn inferences which appear to be reasonable and made general statements (Chapters 5 and 6) on the significance of urban runoff. Where it has been possible or practical to do so, these general screening analyses have been applied to local situations which exist within certain of the individual NURP Projects. Comparisons have been made between specific water quality effects or broader conclusions relative to problems derived from both local analysis and general screening methods. These comparisons are presented in Chapter 6 of the report.

Criteria/Standards and Beneficial Use Effects.

The analysis methods employed make it possible to project water quality effects caused by intermittent urban runoff discharges. Where appropriate, these effects are expressed in terms of the frequency at which a pollutant concentration in the water body is equalled or exceeded. However, if the basis for determining the significance of such water quality impacts (and hence the need for control) is taken to be the effect such receiving water concentrations have on the impairment or denial of a specific beneficial use, then it is necessary to go one step further. A basis is required for judging the degree to which a particular water quality impact constitutes an impairment of a beneficial use. With intermittent pollutant discharges, effects are variable and are best expressed in terms of a probability distribution from which estimates can be made of the frequency with which effects of various magnitude occur.

There is a rather broad consensus that existing water quality criteria, and water uses based on such criteria, are most relevant when considered continuous exposures (ambient conditions). Even where continuous discharges are involved there has been discussion and debate as to whether a particular criterion should be interpreted as some appropriate "average" condition or a "never-to-exceed" limit. The basic issue is whether the more liberal interpretation will provide acceptable protection to the beneficial use for which the criterion in question has been developed. The only reason such distinctions become an issue is because the practical feasibility or relative economics, or both, are sufficiently different that one is encouraged to question whether the more restrictive interpretation is overly (or even excessively) conservative in terms of providing protection for the associated beneficial use.

This issue, whether normal ambient criteria are excessively conservative measures of conditions which provide reasonable assurances of protection for a beneficial use, when exceeded only intermittently, is particularly appropriate in the case of urban storm runoff. Analysis of rainfall records for a wide distribution of locations in the nation indicates that, even in the wetter parts of the country, urban runoff events occur only about 10 percent of the time. There are regional and seasonal differences, but typical values for annual average storm characteristics in the eastern United States are:

	Average (Hours)	Median	90th Percentile (Hours)
Storm Duration	6	4.5	90th = 15 85th = 12.5
Interval Between Storm Mid-Points	80	60	200

In the semi-arid regions of the western half of the country, average storm durations tend to be comparable to the above, but average intervals between successive storms increase substantially (two to four fold). With urban storm runoff, therefore, one is dealing with pollutant discharges which occur over a period of a few hours every several days or more. In advective rivers and streams, the water mass influenced by urban runoff tends to move downstream in relatively discrete pulses. Because of the variability in the magnitude of the pollutant loads from different storm events, only a small percentage of these pulses have high pollutant concentrations.

There are as yet no formal "wet weather" criteria, and thus no generally accepted way intermittent exposures having time scale characteristics typical of urban runoff can be related to use impairment. In the belief that it would be inappropriate to ignore such considerations in a general evaluation of urban runoff, EPA has developed estimates for concentration levels which result in adverse impacts on beneficial use when exposures occur intermittently at intervals/durations typical of urban runoff. These "effects levels" are used to interpret the significance of the variable, intermittent water quality impacts of urban runoff. It should be understood that these effect levels do not represent any formal position taken by EPA, but are simply the most reasonable yardsticks available to meet the immediate needs of the evaluation of urban runoff. As used in the screening analysis procedures, alternative values for "effects levels" may be readily substituted when either more reliable estimates can be made, or more (or less) conservative attitudes are indicated for the importance of a particular water body or beneficial use.

Table 4-1 summarizes available information on water quality criteria for a number of contaminants routinely found in urban storm runoff. The data presented include:

a. Water quality criteria for substances on EPA's Priority pollutant list (45 FR No. 79318, 11/28/80). These criteria provide an extensive set of numerical values derived from bioassay studies.

b. Estimates of "effects levels" which are suggested by NURP analysis to be relevant for the intermittent exposures characteristic of urban runoff.

The rationale and details of the procedure utilized in estimating the effect levels for intermittent discharges, is described in Appendix D.

Problem Definition.

By incorporating the numerical values for EPA's water quality criteria and for intermittent effects in the same table, or on the same graph (Chapter 5), a convenient, concise comparison is provided of the practical implications of applying one or the other as the yardstick for judging the protection or impairment of water use. The two sets of numerical values thus provide measures for two of the three options for defining a problem: violation of criteria or actual impairment of a beneficial use. The third option, local perception of a problem and degree of concern is not addressed by these quantitative procedures.

Comparison of the pollutant concentrations in urban runoff showing the frequency and magnitude of ambient criteria violation with the effects levels for intermittent discharges exceedence, provides a qualitative sense of the control requirements (and implications regarding costs) attendant on the adoption of either problem definition as the operative one.

TABLE 4-1. SUMMARY OF RECEIVING WATER TARGET CONCENTRATIONS USED IN SCREENING ANALYSIS - TOXIC SUBSTANCES (ALL CONCENTRATIONS IN MICROGRAMS/LITER, μg/ℓ)

82-218-1

Contaminant	Water Hardness mg/l (as Ca CO_3)	EPA Toxic Criteria					Estimated Effect Level For Intermittent Exposure	
		Freshwater Aquatic Life		Saltwater Aquatic Life		Human Ingestion		
		24 Hour	Max	24 Hour	Max	(1)	Thresh-hold	Significant Impact
Copper	50	5.6	12	4.0	23	NP	40	500
	150		32					
	300		62					
Zinc	50	47	180	58	170	NP	600	1.600
	150		450					
	300		800					
Lead	50	0.75	74	(25) (C)	(670) (A)	50.0	3/3	4,500
	150	10.0	280					
	300	50.0	660					
Chrome (+3)	50	(44) (C)	2,200	N.P.	(10,300) (A)	170,00	8650	-
	150		7,300					
	300		15,000					
Chrome (+6)	-	0.29	21.0	18	1260	50.0		
Cadmium	50	0.01	1.5	4.5	59.0	10	5.5	10
	150	0.04	4.6					
	300	0.08	9.6					
Nickel	50	56	1090	7.1	140.	13.4		
	150	130	2500					
	300	220	4250					

NOTES:

- Some toxic criteria are related to Total Hardness of receiving water. Where this applies, several values are shown. Other values may be calculated from equations presented in EPA's Criteria Document (Federal Register, 45,231, November 28, 1980). Where a single value is shown, water hardness does not influence toxic criteria.
- Concentration values shown within parentheses( ) are not formal criteria values. They reflect either chronic (C) or acute (A) toxicity concentrations which the EPA toxic criteria document indicated have been observed. Values of this type were reported where the data base was insufficient (according to the formally adopted guidelines which were used in developing the criteria) for EPA to develop 24 hour and Max values.
- Note (1). The "Human Ingestion" criteria developed by the EPA Toxic Criteria documents are indicated to relate to ambient receiving water quality. The Drinking Water Criteria relate to finished water quality at the point of delivery for consumption.
- Estimated Effects levels reflect estimates of the concentration levels which would impair beneficial uses under the kind of exposure conditions which would be produced by Urban Runoff. They are an estimate of the relationship between continuous exposure and intermittent, short duration exposures (several hours once every several days).
- NP = No criteria proposed.

Time Scales of Water Quality Impacts.

There are three types of water quality impacts associated with urban runoff. The first type is characterized by rapid, short-term changes in water quality during and shortly after storm events. Examples of this water quality impact include periodic dissolved oxygen depressions due to oxidation of contaminants, or short-term increases in the receiving water concentrations of one or more toxic contaminants.

Long-term water quality impacts, on the other hand, are caused by contaminants associated with suspended solids that settle in receiving waters and by nutrients which enter receiving water systems with long retention times. In both instances long-term water quality impacts are caused by increased residence times of pollutants in receiving waters. Examples of the long-term water quality impacts include depressed dissolved oxygen caused by the oxidation of organics in bottom sediments, biological accumulation of toxics as a result of up take by organisms in the lead chain, and increased lake entrophication as a result of the recycling of nutrients contributed by urban runoff discharges. The long-term water quality impacts of urban runoff are manifested during normal critical periods such as summer, low stream flow conditions, and/or during sensitive life cycle stages of organisms. Since long-term water quality impacts occur during normal critical periods, it is necessary to distinguish between the relative contribution of urban runoff and the contribution from other sources, such as treatment plant discharges and other non-point sources. A site-specific analysis is required to determine the impact of various types of pollutants during critical periods.

A third type of receiving water impact is related to the quantity or physical aspects of flow and includes short-term water quality effects caused by scour and resuspension of pollutants previously deposited in the sediments. This category of impact is not being addressed by the NURP program, in general, although one project is expected to provide some information.

As indicated previously, the first type of change in water quality associated with discharges from urban runoff is characterized by short-term degradation during and shortly after storm events. The intensity of rainfall at a location can vary from minute to minute, and the intensity at any time can be different at two locations. The rainfall process is highly variable in both time and space. Phenomena which are driven by rainfall such as urban runoff and associated pollutant loadings are at least as variable. Measurements can be obtained, at a limited number of locations, on a time scale of minutes to define rainfall, the runoff flow hydrograph, and concentrations of contaminants (pollutographs). These short-time scale measurements have usually been employed in an attempt to refine or calibrate calculation procedures for estimating runoff flows and loads. Most urban areas contain a network of drainage systems which collect and discharge urban runoff into one or more receiving water bodies. Since the rainfall, runoff, and pollutant loads vary in both time and space, it is impossible to determine by calculation or measurement the very short time scale (minute-to-minute) changes in water quality of a receiving water and assign the changes to specific sources of runoff. Although very short duration exposures (on the order of minutes) to very high concentrations of toxics can produce environmental damage (mortality or sublethal effects) to aquatic organisms, it is likely that exposures on the order of hours have the highest possibility of causing adverse environmental impacts. This results, in part, from the smoothing obtained by mixing numerous sources which have high frequency (short-term) variability.

In view of the above discussion, the time scale used by NURP for analysis of receiving water impacts is the rainfall event time scale which is on the order of hours. To represent the average concentration of pollutants in urban runoff produced during such an event, NURP used the event mean concentration.

Rivers and Streams.

Pollutant discharges during storm events independently on water quality in rivers or streams because the loading pulse from one event will be transported some distance downstream before loads from the next storm event are discharged. An additional important factor that must be taken into account by the analysis procedure is the diluting flow in the stream. The available diagram is also a variable element and may be largely or only partially independent of the urban storm runoff flow. Urban runoff may be a minor or a substantial component of total stream flow during runoff periods.

The analysis procedure, described in more detail in Appendix C, essentially operates as follows:

a. Stream concentrations of a pollutant are considered to result from the combination of up stream flow at background concentration and runoff flow at its concentration. Variations in stream concentrations below the urban runoff discharge result from variations in each of these inputs; the most significant source of variation being whether or not an event is occurring, i.e., whether runoff flows and loads are present.

   - Stream flows must be considered because of the major effect of dilution on the resulting concentrations. However, upstream concentrations can be set at zero for the calculations -- in which case the result obtained is the exclusive effect of urban runoff discharges, and not the overall expected stream concentration.

   - Effects of urban runoff can be evaluated by considering only the periods during which runoff occurs.

b. Each of the input parameters is assumed to be adequately characterized by a log-normal distribution; from analysis of data, or other estimating procedures, the statistical properties of each of the input parameter distributions are defined.

   Estimates for runoff flows and concentrations are developed from information derived from the NURP monitoring programs. Information on stream flow can be obtained from analysis of local stream gage records, or initially estimated as described in Appendix C. Upstream concentrations tend to be very site-specific; for this reason, the screening analysis calculated only the effect of urban runoff discharges.

c. From the statistical properties (specifically, the arithmetic mean and standard deviation) of the flows and concentrations, properties of the dilution ratio can be defined and the statistical properties of the resulting in-stream concentrations are calculated directly.

d. The frequency with which any particular target concentration is exceeded during wet weather can be calculated from the statistical properties of stream concentration, using formulas or scaled directly from a standard plot of cumulative log-normal distributions.

The frequency with which the target concentration is exceeded during all periods -- wet and dry -- is simply the product of the wet weather frequency and the probability (frequency) that it is raining. The probability that it is raining at any time is defined by D/Δ derived from the rainfall statistics.

$$\frac{D = \text{mean duration of storms}}{\Delta = \text{mean interval between storm midpoints}} = \text{fraction of time it is wet}$$

e. In the presentation of results in Chapter 5, the probability distribution of event mean stream concentrations of an urban runoff pollutant during runoff periods is converted to a Mean Recurrence Interval (MRI) as a device to assist in the interpretation of results. The recurrence interval is defined as the reciprocal of probability. Because the basic calculation is based on storm events, this definition yields the overall average number of storms between specific event occurrences. Event recurrence is converted to what is believed to be a more meaningful time recurrence by dividing by the average number of storms per year, which is developed from analysis of rainfall records.

Currently, the primary use of the above procedure is as a screening tool in which approximate results and relative values are of interest. In this regard, NURP believes the Mean Recurrence Interval is a very useful definition. It should be interpreted as the long-term average interval between occurrences.

Lakes.

The method used to determine lake responses to nutrient loads is discussed in Appendix C.

For lake eutrophication problems, the time scale for analysis is considerably longer than the short (event scale) periods necessary for estuaries and rivers. Annual average loads are used, and a steady state analysis is performed using the type of empirical model advanced by Vollenweider and others.

The mass loading information developed from NURP monitoring programs can be readily converted to annual loads. Average concentrations of total phosphorus are calculated using the following formula:

$$P = \frac{W'}{H/\tau + \upsilon_s} \cdot 1000$$

The input values include pollutant mass loading (W'), lake physical characteristics (H, τ), and reaction rate coefficients (υ_s). The relative contribution of all load sources to lake total P concentrations can be defined by solving this equation for each of the sources. By comparing results in terms of lake concentration for initial conditions (no control), and then modifying loads to reflect various levels of control, alternative control operations can be compared directly to effect on lake water quality.

Comparisons may be made using either phosphorus concentrations, or using chlorophyll a and secchi depth - which are derived from calculated phosphorus concentrations by regression equations. Judgments on acceptable lake water quality depend in part on the water use and on regional norms and expectations. As an example, many lake water quality criteria were orginally developed for northern temperate zone lakes, and consider chlorophyll levels between 10 and 20 µg/l as upper limits on water quality objectives. By contrast, lakes in southern regions of the country can often be judged to have acceptable water quality with chlorophyll levels of 30 to 50 µg/l.

Estuaries.

The method used to predict mean response to variable, intermittent loads in estuaries and tidal rivers, and the variability of this response is discussed in Appendix C.

Based on information developed in NURP monitoring programs on the mean and coefficient of variation of the mass load of the pollutant of concern which is discharged to the receiving water, the mean and standard deviation of the resulting concentration (c and σ_c) in a tidal water body is calculated (for the one-dimensional case, i.e., no stratification) by substituting appropriate values in the following formulae:

Mean concentration ($\bar{c}$) in estuary:

$$\bar{C} = \frac{M_R/\Delta}{U\,A\,m} \exp \frac{U\,x}{2E} \;(1 \pm m) \quad \cdot (3.04)$$

Standard deviation (σ_c) of estuary concentration:

$$\sigma_c = \sqrt{\frac{\sigma_m^2 + M_R^{\,2}}{A\,\sqrt{2\pi E\Delta}}} \exp\left(\frac{U\,x}{2E}\right) K^{\frac{1}{2}}{}_o \left(\frac{U\,x\,m}{E}\right) \quad \cdot (3.04)$$

The input values are described in Appendix C. They include pollutant load data (M_R, σ_M), receiving water physical characteristics (U, A), and rate coefficients (E, K). The equations can be solved for selected locations at a distance (X) from the discharge location, upstream or downstream. Receiving water impacts can be determined initially for existing conditions (no controls), and subsequently using modified pollutant mass loading data which reflect the specific levels of urban runoff control being evaluated.

For each condition and receiving water location of interest, the mean ($\bar{c}$) and standard deviation (σ_c) of the resulting estuary concentration is determined. Frequency of occurrence of a receiving water concentration of any magnitude can be calculated from the statistical properties of the estuary concentration resulting from the urban storm runoff loads, or scaled from standard graphs.

EVALUATION OF CONTROLS

General.

The evaluation of controls has two elements: (a) characterizing the controls' performance capabilities and (b) defining costs. For this preliminary report, only the characterization of performance is addressed. Cost information is being developed by EPA under separate supporting contracts, and results are not yet available.

EPA's Office of Water Regulation and Standards (OWRS) is providing, under contract, a national-level economic analysis of a program to control urban runoff. The purpose of the study is to develop national cost estimates for the abatement of urban stormwater runoff pollution. The study will concentrate on those receiving waters where a particular use has been or could potentially be impaired by urban runoff. The report of the analysis is due in July, 1982.

A parallel effort by OWRS, being performed under a separate contract, involves the collection of the cost data associated with best management practices being tested under the NURP program. This effort will provide the data for the economic analysis. This report is due in March, 1982.

Results are quite preliminary at this time, because the availability of data in this category is still quite limited. Analysis procedures are also preliminary, because the final choice will be influenced by the nature, quantity, and comprehensiveness of data ultimately available.

At this time sufficient information is available for preliminary analysis of performance of three control measures. Others will be added as information becomes available.

Retention/Detention Basins.

Appendix C presents a review of a variety of procedures which can be considered for evaluation of this type of device. Procedures adopted by individual projects testing retention basins are described in project reports. Available preliminary results are presented in Chapter 5.

For this overview analysis, the initial approach taken is dictated by NURP's access to data at this time, and is considered very preliminary.

The data currently accessible in STORET have been searched, and all water quality data corresponding to (a) influent and (b) effluent from a retention pond have been assembled and pooled. Statistical parameters for influents and effluents have been determined. These are compared in Chapter 5.

There are some obvious, legitimate reservations concerning the suitability of this approach. This analysis fails to develop an understanding of how detection ponds work. Overall performance will be a function of the size of the basin relative to the size of the urban drainage area it serves. The basins will perform better on small storms than on larger ones. There is no assurance from the analysis performed, that there is a representative balance between influent and effluent event characteristics. (A significant percentage of the currently available data are not synoptic: influent data and effluent data are not for the same event.)

The justification for the analysis performed is that it is an informative first step, provided appropriate judgment is exercised in interpretation of the results. NURP suggests that a good clue as to what may be expected from more rigorous analysis is provided by the general order of the outcome from the pooled data comparison. That is, whether indicated removals are substantial, nominal or marginal.

Street Sweeping.

A detailed analysis has been performed by a number of the projects in which street sweeping is a principal subject of investigation. Procedures are described in individual project reports, and some results are summarized in Chapter 5. An outline of possible analytical methods for evaluating this control measure is presented in Appendix C.

A screening has been performed for this preliminary report, using the same procedure and rationale as described above for retention basins. Pooled data on the runoff from urban catchments have been assembled and analyzed using comparisons for periods when the study areas were swept vs unswept. Again no breakout has been made in these preliminary results, as a function of sweeping frequency or climatological or other factors which might influence results.

Recharge Basins.

This category includes impoundments or other structures such as percolating catch basins, in-line percolation chambers or perforated pipes, or swales, which function by intercepting some portion of storm runoff and allowing it to percolate into the ground. Although several projects are evaluating performance of such devices, sufficient performance data for a general evaluation are not yet available.

One of the basic questions which arises when controls of this type are considered is whether the percolation encouraged will produce undesirable degradation of ground water. However, since NURP results to date suggest that the contaminants typically found in urban runoff in significant concentrations are effectively separated in the percolation process, there is encouragement to continue exploring the effectiveness of this process.

Evaluation of percolating basins of any size is readily accomplished using the standard storage/treatment routines of stormwater models such as STORM or SWMM. In such cases the local soil permeability (the percolation rate) is applied as the treatment rate. For the screening analysis utilized the statistical analysis procedures described in "A Statistical Method for the Assessment of URBAN STORMWATER" - (EPA 440/3-79-023 May 1979) - results from which closely approximate results from the mathematical model simulators.

QUALITY ASSURANCE AND QUALITY CONTROL (QA/QC)

General.

Because data collection and analysis forms one of the most important information sources for the NURP, it is essential that the monitoring and analysis programs produce sound data. The need for comparability, transferability, and nationwide determinations mandated the inclusion of QA/QC by all designated prototype projects. Accordingly, from its inception, NURP required that all projects incorporate QA/QC elements as integral parts of their work plans.

The sections below briefly describe the various elements in the overall QA/QC program. Specific details are provided in the documents cited in each section, which were distributed to the individual NURP projects over the course of the program.

Program Coordination.

Clear assignment of responsibility is essential in establishing a workable quality assurance (QA) program. Therefore, it was required of each project that a QA coordinator be designated and given responsibility for the entire QA effort. Among other duties, the coordinator is responsible for developing and implementing an inter- and intra-laboratory quality control program. Guidance was provided on the qualifications for the position.

Laboratory Quality Assurance.

The guidance provided for lab QA is a handbook prepared by EPA's Environmental Monitoring and Support Laboratory (EMSL). This handbook provides the analytical quality control information to allow inauguration or reinforcement of a program that will emphasize early recognition, prevention and correction of factors leading to breakdowns in the validity of data from water and wastewater laboratories.

Field Quality Assurance.

Quality assurance in the field was stressed as it is probably one of the most slighted aspects of any monitoring QA program. Guidance was provided for all key aspects of the data collection process. Guidance was provided on the sample collection, which covers split and spiked samples, sample preservation, and precision, accuracy and control charts. Again, documents developed by EPA and others were referenced (see references). Other areas covered were equipment calibration, sample handling and shipping, and special precautions for certain pollutants and parameters. Chain of custody procedures were explained and suggestions provided. Sampler and equipment cleaning was covered.

Data Management.

A manual entitled "Data Management Procedures" was provided to all participating NURP projects and others interested in the program. The manual provides methods on formatting, data reduction, and some analysis. The objective of this guidance is to provide a data base with compatible inputs from all NURP projects for the determination of urban stormwater impacts nationwide and also to provide a uniform data analysis framework for all NURP and non-NURP projects.

Data Analysis.

Uniform methods of analysis were not stressed. Any method the project director preferred was encouraged. Correct application of the analytical procedures was stressed. During the course of this program several technical memoranda were issued to provide consistent guidance to all projects on any changes, improvements, etc., as they occurred.

CHAPTER 5
FINDINGS

INTRODUCTION

This chapter presents condensed summaries of data derived from selected NURP projects and preliminary interpretations and conclusions resulting from application of the analytical methodologies described in the previous chapter.

Emphasis is placed on developing a "national overview", which will later be based on data pooled from all projects. This section also focuses on determining patterns of the similarities and differences in regional or site-specific characteristics because these patterns determine the transferability of findings among projects.

Local (i.e., project-specific) findings and conclusions available at this time are presented in the project summaries provided as Appendix E. Where pertinent or appropriate, NURP attempted to report local conclusions which bear on the findings derived from our summation of the project results. NURP also attempted to give emphasis to those local conclusions which may disagree or conflict with the conclusions presented in this report. Chapter 6 includes a broader discussion of conclusions from both local and national efforts.

It is important to note that this is a preliminary report, based on a relatively small portion of the total data base that will be available at the conclusion of NURP project effort. Some data have been developed to date, and much more are still in the process of acquisition and preparation. The following assessment utilizes this limited pilot data base as though it were fully representative of the overall data base which will be available and accessible within the next 12 months. It is recognized that some (or many) of the results and conclusions presented may change in the final report. Our present belief is that they are more likely to change in degree rather than in kind, but that remains to be seen. The principal purpose in adopting this approach of analyzing a premature data base was to illustrate (1) how the data and results will be analyzed and interpreted; (2) the nature of the conclusions NURP seeks to draw from the data; and (3) the rationale NURP currently proposes to apply in deriving decisions and recommendations. This approach also provides reviewers, particularly those representing the individual projects, with an opportunity to provide comments and contribute to the "national" aspect of the overall NURP effort.

This chapter is organized so that each of the three fundamental elements of the urban runoff issue is addressed separately. The subsections which follow are:

Loadings. This section addresses concentrations and mass loadings of specific pollutants and runoff flows. It presents results using pooled data from the selected NURP projects. The degree of transferability of data is analyzed. Pertinent conclusions or results from selected projects are summarized where they conflict or suggest an exception to the generalizations developed. NURP results are compared with other published sources of similar information. Results of an analysis characterizing nationwide conditions are presented. It should be noted that the pilot data base and the analyses presented in this interim report deal only with concentrations. A similar analysis will be made for mass loads as soon as the necessary flow monitoring data are finalized by the projects and entered into the NURP data base.

Impacts on Receiving Waters. This section summarizes evidence regarding the concept that urban runoff causes water quality problems. Because of unique characteristics of different types of receiving water bodies, an approach using "pooled data" from many projects cannot be taken, as was done for loadings. Results from the NURP projects which quantitatively assessed receiving water impacts have been summarized. Emphasis is on quantifiable physical/chemical/biological effects. The results of a screening analysis are summarized to indicate the conditions under which problems could be expected for various constituents. This provides a basis for drawing inferences concerning the likely significance of urban runoff as a national-scale water pollution problem.

An evaluation of the threefold "problem" definition is presented. The discussion is based on inferences drawn from the screening analysis and from individual project conclusions.

Controls. This section addresses control measures in the format used above. An evaluation was made using the methodology described in the previous chapter and based on pooled data from project results (supplemented by published data). The following topics are addressed:

> Performance Characteristics. An assessment of the controls' technical effectiveness (i.e., their removal efficiency for specific pollutants, based on design characteristics and site conditions).
>
> Cost Characteristics. An assessment of the controls' capital, operating, and maintenance costs.
>
> Pollution Control Characteristics. A combined assessment of a controls' effort, effectiveness, and degree of application (e.g., number of basins, street sweeping frequency, area of coverage) necessary to provide various reductions in pollutant loads.
>
> Cost Effectiveness. An assessment of the unit cost of pollutant removal and the unit cost of reducing loads on receiving waters.

LOADINGS

Conventional Pollutants.

Field monitoring was conducted to characterize urban runoff flows and pollutant concentrations and mass loadings. This was done for a variety of pollutants at a substantial number of sites distributed throughout the country. The resultant data represent a cross-section of regional climatology, land use types, slopes, and soil conditions and thereby provides a basis for identifying patterns of similarities or differences and testing for their significance. To meet the objective of maximizing the degree of transferability of urban runoff data, the NURP approach involved covering a spectrum of regional and land use characteristics, requiring consistent quality assurance programs among all projects, and encouraging each of the projects to obtain data for a statistically significant number of storm events at a site.

It should be understood that "loading" data include factors such as urban runoff flows, concentrations of contaminants, and mass loadings (which reflect the combined influence of flow and concentration). Each of these factors is quite variable. Review of earlier data and the experience of team members indicated wide variations from sample-to-sample within a given storm, from storm-to-storm at a given site, from site-to-site within the same city, and from city-to-city. The approach used here in the analysis of loading data was designed to seek a way to identify significant patterns of basic similarities or basic differences within the "noise" of random fluctuations.

Table 5-1 summarizes the sources of the data utilized in this preliminary analysis. The analysis of the pilot data set reported here illustrates the statistical approaches developed for the overall program. In fact, however, even our limited pilot data set is appreciably larger than the aggregate of all data available from all previous studies. It has the added advantage of uniform quality control and has been screened so that only "end of pipe" urban runoff discharges (i.e., those which are free of influence from upstream control measures or known extraneous sources of contamination) are included for analysis.

Event mean concentration data from 13 projects (representing 824 separate storm events) were analyzed for this interim report. Substantially more data have been collected by the projects and will be utilized in a similar analysis for the next draft of this report. The size of the interim sample is determined by the amount of data currently accessible from the STORET data base (which provides an efficient means for processing the extremely large number of individual data entries).

Statistical analysis procedures described in Appendix C were applied to the event mean concentration (EMC) data, and each of the five pollutants analyzed in the pilot data set were determined to be well represented by an underlying probability distribution which is log-normal. Figures 5-1(a) and 5-1(b) shows the log probability distributions of the data in the current data base.

Figure 5-2 summarizes the distribution of event mean concentrations for the 51 sites represented in the pilot data set. Concentrations of selected pollutants in urban runoff (e.g., total phosphorus, total lead, total copper, total COD and total suspended solids) are shown in the form of probability distributions.

Table 5-2 summarizes these data in tabular form and compares the results with data summarized from previously reported studies. Appendix B (Data Summary) provides a listing of data for each NURP project and site used in the pilot data set analyzed here.

A graphical presentation has been used (see Figure 5-3) because it facilitates comparing results from the significant available sources. In comparing

TABLE 5-1. SOURCES OF DATA

Zone	Project	No. of Sites	No. of Events	Event Totals
Northeast (1)	NH - Durham	1	21	
	MA - Lake Quinsigamond	6	45	66
Mid-Atlantic (2)	DC - Washington	8	94	
	NC - Winston-Salem	2	45	139
Midwest(3)	MI - Ann Arbor	4	34	
	MI - Lansing	4	41	
	IL - Chicago	1	8	
	IL - Champaign	5	91	
	WI - Milwaukee	8	222	
	SD - Rapid City	1	6	402
High Plains (4)	CO - Denver	7	56	56
Northwest (5)	WA - Bellevue	2	133	133
-	TX - Austin	2	28	28
TOTALS	13	51	824	

NOTES:

- Determinations were not made for every constituent for every event.
- The site event total for Austin is too small to allow it to be considered a region (southwest).
- Numbers ( ) represent NURP zones and are sometimes referred to for brevity.

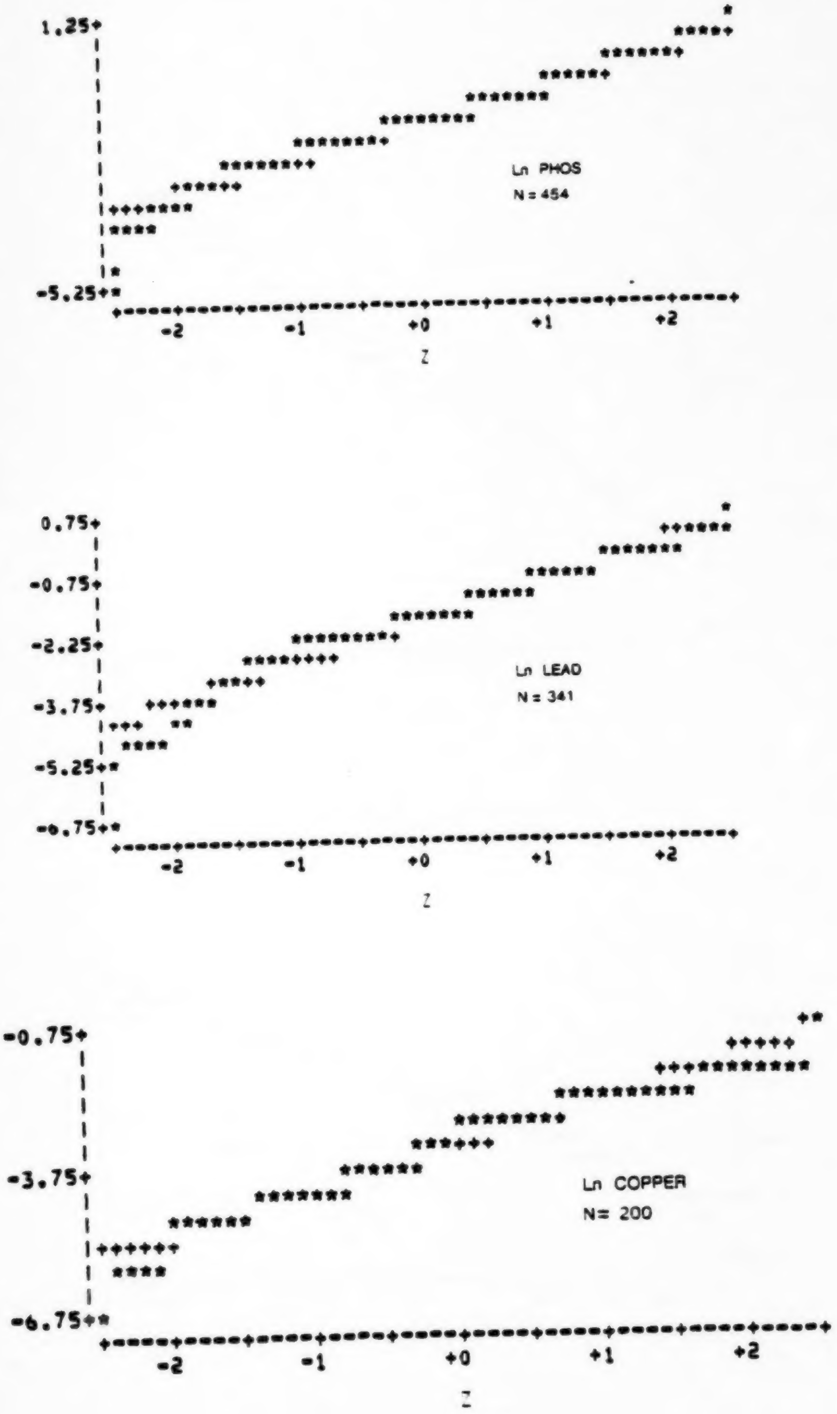

Figure 5-1(a). Cumulative Probability Plots in Log-Space

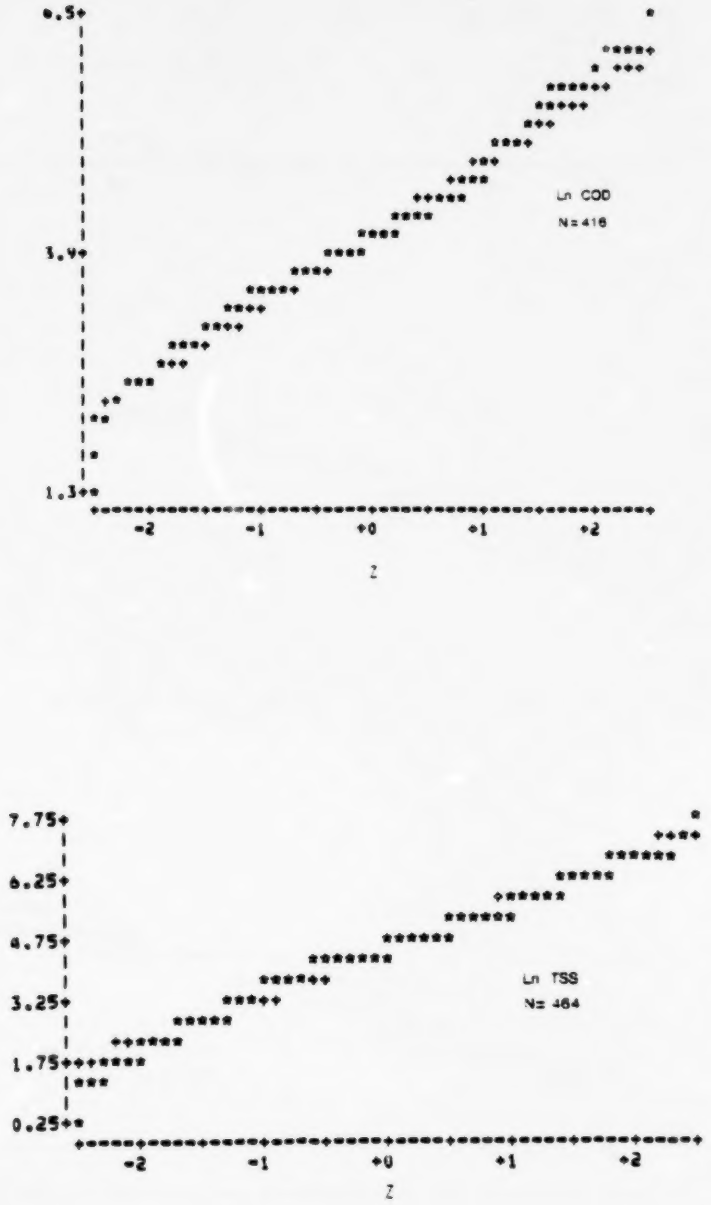

Figure 5-1(b). Cumulative Probability Plots in Log-Space

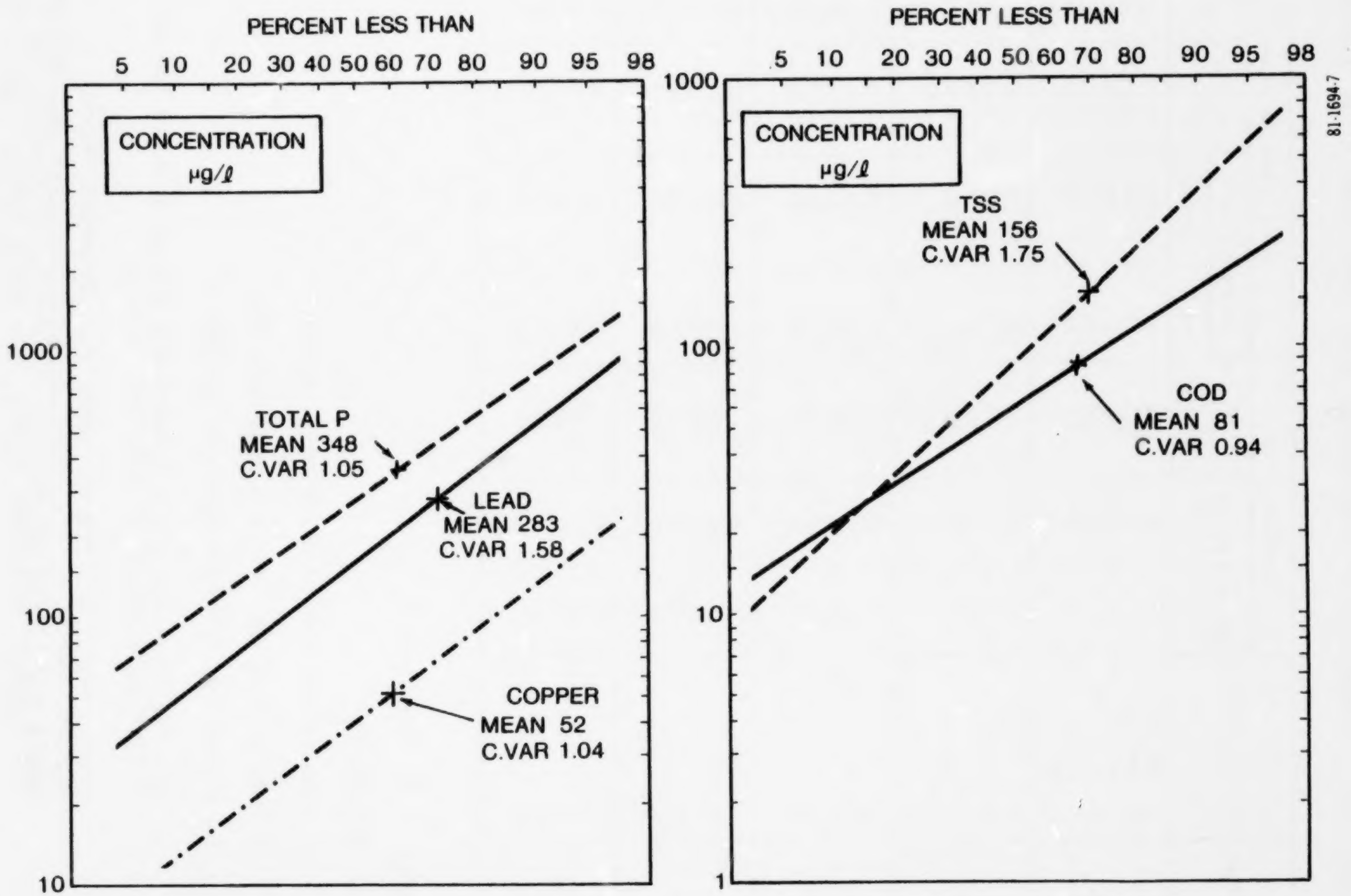

Figure 5-2. Pollutant Concentration in Urban Runoff Event Means
(Preliminary NURP Data - 13 Projects)

TABLE 5-2. COMPARISON OF PRELIMINARY NURP DATA WITH PRIOR SUMMARIES

82-218-6

Pollutant	Data Source(1)	Observations(2)			U.R.O. (Separate Sewers)			
		No. of Cities	No. of Sites	No. of Events Monitored	Concentration(3)		Coef of Variat.	Range(4)
					Mean	Median		
COD mg/ℓ	A. NURP #1	6	23	181	67	57	0.61	30 - 120
	B. NURP #2	12	40	428	81	60	0.90	20 - 160
	C. NURP #3	13	51	709	81	59	0.94	20 - 165
	D. U of F 1979	9	15	138	90	77	0.60	40 - 160
	E. U of F 1981	15	18	204	81	69	0.61	30 - 140
	F. M&E	-	-	-	-	-	-	45 - 180
TSS mg/ℓ	A.	6	23	232	108	2	1.42	20 - 250
	B.	12	40	276	171	90	1.63	20 - 400
	C.	13	51	790	156	77	1.75	17 - 355
	D.	9	17	210	350	161	1.90	30 - 800
	E.	15	31	263	560	268	1.83	60 - 1200
	F.	-	-	-	-	-	-	150 - 1200
Total P µg/ℓ	A.	6	23	220	395	278	1.01	95 - 815
	B.	12	40	466	397	280	1.01	100 - 820
	C.	13	51	737	348	240	1.05	80 - 730
	D.	9	8	114	510	392	0.83	150 - 1000
	E.	15	13	219	386	265	1.06	90 - 800
	F.	-	-	-	-	-	-	350 - 1000
LEAD µg/ℓ	A.	6	23	123	256	138	1.57	30 - 580
	B.	12	40	343	251	159	1.22	50 - 540
	C.	13	51	662	283	152	1.58	40 - 640
	D.	9	9	106	172	161	0.37	100 - 250
	E.	15	16	210	294	242	0.69	110 - 540
	F.	-	-	-	-	-	-	150 - 700
COPPER µg/ℓ	A.	6	23	113	57	47	0.68	20 - 100
	B.	12	40	200	62	41	1.15	10 - 130
	C.	13	51	280	52	36	1.04	10 - 110
	D.	9	7	41	91	51	1.50	10 - 200
	E.	15	12	131	61	33	1.60	8 - 140
	F.	-	-	-	-	-	-	-

NOTES - (for Table 5-2)

(1) DATA SOURCES

A. Analysis of NURP DATA available Aug 1981

B. Analysis of NURP DATA available Sept 1981

C. Analysis of NURP DATA available Jan 1982

D. Extracted from analysis of summary data available in the "University of Florida Data Base" in 1979, and presented in:

Huber, Wayne C., Heaney, James P., Smolenyak, Kevin, J., and Aggidis, Demitrios A., Urban Rainfall-Runoff-Quality Data Base: Update with Statistical Analysis, University of Florida, for U.S. Environmental Protection Agency, EPA-600-8-79-004, August, 1979.

E. Unpublished data available in the "University of Florida Data Base" in Sept., 1981. Extracted from analysis of printout of current data inventory provided by Wayne C. Huber and James. P. Heaney.

F. Extracted from summaries available in 1977 and presented in:

Lager, John A., W. G. Smith, W. G. Lynard, R. M. Flynn, and E. J. Finnemore, Urban Stormwater Management and Technology: Update and Users Guide, Metcalf and Eddy, Inc. for U.S. Environmental Protection Agency, EPA-600/8-77-014, September, 1977.

(2) OBSERVATIONS

Indicates the number of cities represented in the respective data bases. The number of sites reflects the fact that each city is represented by a varying number of monitored catchments (from 1 to 14), and the fact that not all sites measured all parameters. Number of events reflects the overall total of individual storm events from all sites which were monitored. Number of monitored events at a particular site ranged from two or three to several dozen.

(3) CONCENTRATIONS

Results reported are derived from statistical analysis of available data. Concentration variations within a storm event are not particularly significant for present purposes, and are not reflected by the data summary.

Each "observation" reported is based on a flow weighted average concentration of a pollutant in a particular storm event.

The NURP results shown in this table were derived from statistical analysis of the individual event mean concentrations (EMC's), from all sites.

The University of Florida Data Base summary available for processing, had consolidated each set of EMC's at a particular site, into a flow weighted site mean concentration (SMC). The summary in this table represents a statistical analysis of SMC's generated from the format adopted in this data base.

The NURP and University of Florida summaries therefore represent similar, though not exactly the same, statistics. More direct comparisons will be made for the next update of this report, by developing site mean concentrations for NURP Data, and by analyzing individual events from the University of Florida data base.

(4) RANGE

The range reported by M&E (source F) is derived from bar charts presented in their report. Individual data were not available for calculating the other values presented in the comparisons - nor is it deemed worthwhile to do, given the early date for the sources included.

The ranges shown for both NURP and University of Florida Summaries represent the interval between the 10 percent and 90 percent exceedance values, calculated from the probability distribution derived from statistical analysis of the data. Values listed have been rounded.

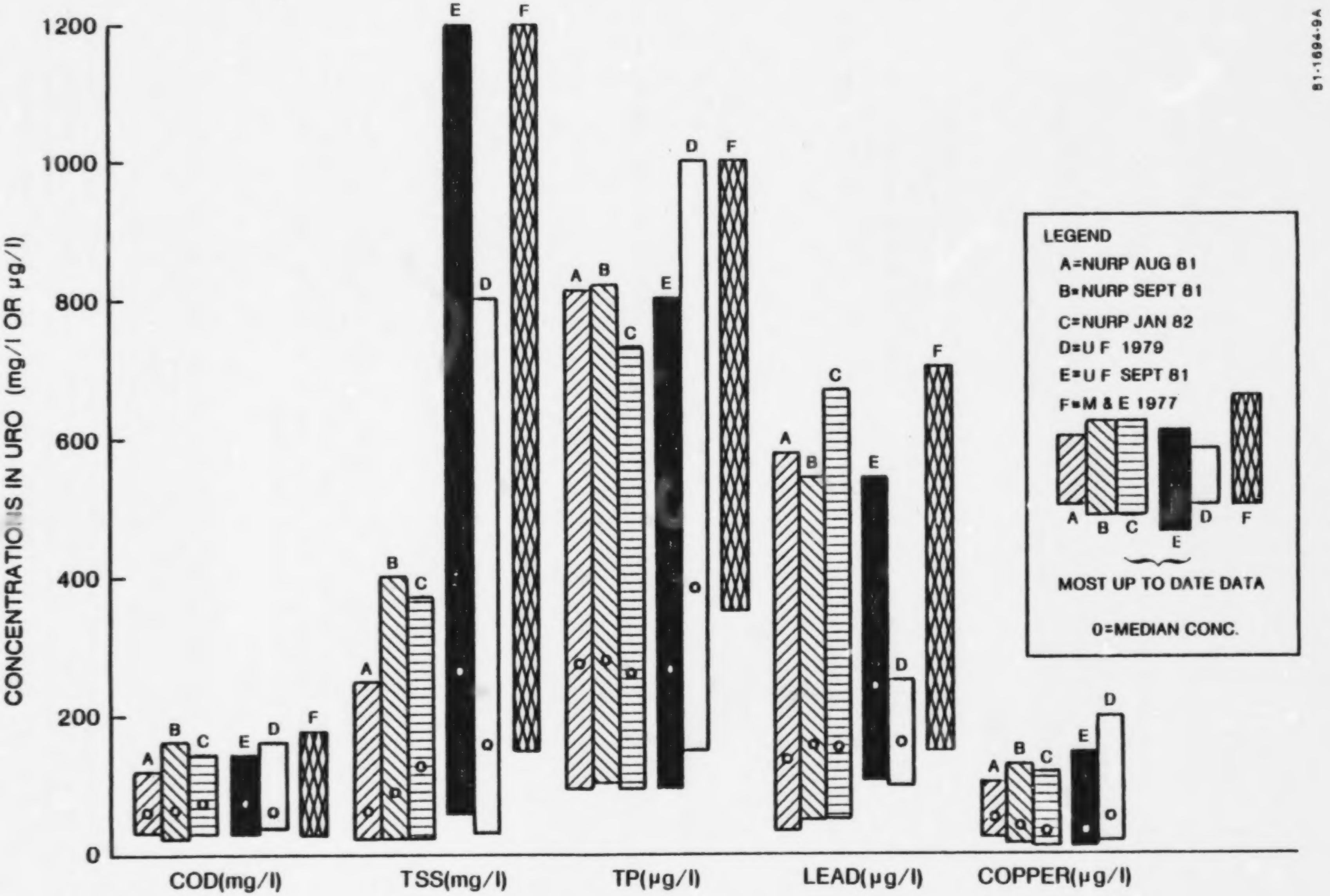

Figure 5-3. Comparison of NURP Results with Other Studies

data from different studies, it should be recognized that the more limited the data sources, the more the particular data set will tend to be biased if the results from a few sources constitute a large percentage of the total results for that data set. For example, the 1979 version of the University of Florida data base for copper and lead is dominated by results from Seattle (approximately 80 percent of the sites and 80 percent of the monitored events were in Seattle). Subsequent versions of this data base, which reflect the inclusion of data from additional locations, tend to reduce the degree of bias. A more balanced distribution of data sources for COD and TSS in this same data base, shows results more compatible with other general sources. The 1981 version of the University of Florida data base provides a considerably broadened basis for such analyses, but it tends to be influenced by having a large proportion of its additional sites located in one place (i.e., Chicago). This concept is noted here to explain that the pilot data set from the NURP projects is probably also biased toward the particular conditions (site characteristics, type of storms) which its sources reflect. When more data are introduced by more sources, the bias will be damped out.

For this reason, the indications portrayed by the summaries in this interim report should be considered preliminary and tentative. A significant advantage of the eventual NURP data base is that its large size and broad distribution (region, land use, etc.) should be sufficient to damp out most bias which might be associated with a given source or local condition. At the same time, the statistical methodology being utilized in analyzing and interpreting the data provides a basis for recognizing the fact that results are variable and may or may not differ significantly from location to location. It also provides a formal and quantitative basis for describing similarities or differences.

The spreads shown by the bar charts (Figure 5-3) provide a sense of the variability inherent in urban runoff pollutant concentrations. Note that the spread is greater for some pollutants than for others. It also suggests, however, that the possible and likely ranges can be defined. Median values, shown by dots in the bar charts, also suggest (at this preliminary stage) that a typical value for a mean concentration can be defined within an acceptably narrow range.

Examination of Figure 5-4 can provide a useful perspective on the use of ranges to describe urban runoff contaminant concentrations. A fairly common approach to describing and summarizing variable urban runoff concentration data, has been to cite the range and perhaps the mean of the concentrations observed in a particular study. Where data are limited, this may be a practical way to summarize highly variable results; however, this has a tendency to overemphasize the significance of the maximum observed values.

Figure 5-4 elaborates on the information presented earlier (in Figure 5-3) and shows differences in concentrations among the arbitrarily delineated regions covered by the NURP pilot data set. The range plots presented have

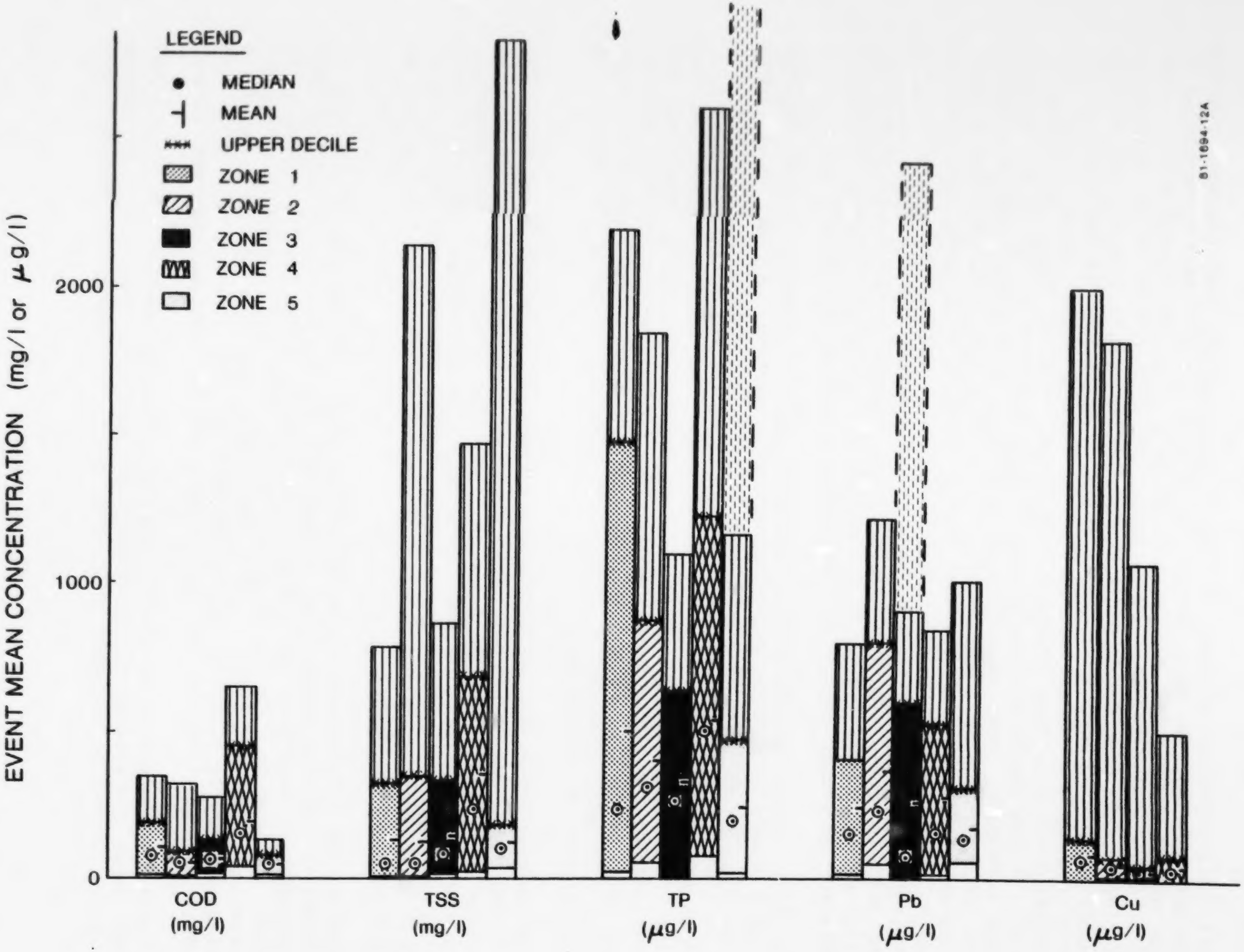

Figure 5-4. Urban Runoff Concentration Ranges for NURP Pilot Data

identified the median, the mean, the upper decile (i.e., the concentration exceeded by only 10 percent of the observed values) and the total range.

The highest data point for two sets (i.e., Zone 5 total phosphorus and Zone 3 lead) were so far above the next few highest points that their credibility is presently in question, so they are indicated by dashed lines.

Keeping in mind that the solid portion of each bar contains 90 percent of the observations, one can see that it could be misleading to think in terms of concentration ranges, without considering the appropriate qualifications. The copper data most dramatically demonstrate this point, but in the majority of instances the solid portion of the bar is less than half of the total length. The fact that these contaminant concentrations have been demonstrated to have log-normal distributions permits these statements on ranges to be made with confidence.

There are some high concentrations at the upper end of the range, but they occur much less frequently than do the concentrations closer to the median. Where the ultimate concern is the effect of a particular contaminant on the beneficial use of a receiving water body, the issue of "how often" is usually as important as "how much". Use of the statistical properties of the variable urban runoff concentrations to address this issue is described later.

It is useful to consider the fact that, where the ultimate objective of defining urban runoff concentrations of contaminants is the quantification of a water quality problem or a decision on control, what is really needed is information on representative concentrations and loads from an entire urban area, or a major segment of the area. Where data from a particular city are derived from only a few sites, it is presently unclear whether the best estimate of urban runoff loads for the entire city will be obtained by extrapolating the local data or adjusting the broader national data. Both possibilities will be examined in subsequent analysis of the expanding NURP data base.

Examination of Sub-Populations.

Although the pooled data from the pilot data set (i.e., from all 51 sites at 13 different geographical locations) was demonstrated to have a log-normal distribution for each constituent event mean concentration considered, it is possible that the total population of any given constituent (COD for example) could be composed of two or more distinct sub-populations. These sub-populations could result from factors thought to result in significant differences between events (e.g., geographical region, type of land use, rainfall patterns).

A methodology was developed to examine the statistics in an organized, rigorous manner. Data were screened to identify statistically significant differences on the basis of geographic region (Northeast, Mid-Atlantic, Midwest, High Plain, and Northwest), season of the year (spring, summer, and fall), size of the rainfall event (less than 0.3 inches, 0.3 to 1 inch, and over 1 inch), predominant land use (residential, commercial, industrial, park and open space, and mixed), and representative catchment slope (shallow and steep). These potential influencing factors were selected from many factors listed in the "Fixed Site Data Base" (which characterizes each of the urban catchments). The factors selected were those which had complete data, were available, and which had been summarized in a conveniently accessible form at the time of analysis.

Two screening tests were used to detect subpopulations: the analysis of variance (ANOVA) using the F-test and Duncan's multiple range test. Because the data strongly exhibit a log-normal distribution, these tests were performed on the log-transformed data set.

The results of this screening are summarized in Table 5-3. Note that roughly one-third or more of the total variance present in the data can be explained by only these sub-populations and their first order interactions.

The pilot data base is not sufficiently large to warrant making an appropriate interpretation of subpopulation characteristics, but this will be possible later and will provide the basis for examining transferability and extension of urban runoff load data. This size constraint is clearly indicated in Table 5-4 where the data set attributes are summarized. Note, for example, that the entire Northwest region is represented by only two sites (both are residential), land use is very unbalanced (there are only three commercial, three park, and one industrial out of the 38 sites), and over half the "spring" events occurred in the Mid-Atlantic region. Such substantial biases in the pilot data set will be rectified when more data are included in subsequent analyses. However, for illustration purposes, one approach to organizing such data for interpretation is given in Tables 5-5 through 5-8. The values presented are the ratio of the median of the particular subpopulation to the median of the entire pooled data set, for each pollutant. If these data were representative of the total NURP data base, one might be able to draw conclusions such as those in the following paragraphs.

Table 5-5 illustrates apparent regional trends. It indicates that urban runoff concentrations in Northwest are appreciably lower in oxygen demanding substances and nutrients than the nation as a whole. For other water quality constituents, it is about average. It indicates that urban runoff concentrations in the High Plains region are significantly higher than the rest of the nation, except for heavy metals, which are average or less. It indicates that the Midwest region is typical of the nation as a whole. Lead and copper concentrations are shown to be especially high in the Northeast regions.

Figure 5-5 provides a graphical illustration of the zonal differences in concentrations of COD, total suspended solids, total phosphorus, lead and copper, using the pilot data set. The ranges shown cover event concentrations that are exceeded by more than 10 percent but less than 90 percent of the observed values. The points which are plotted represent median concentrations (i.e., half the observed values are lower than these concentrations), which are identical to geometric means for log-normal data.

Table 5-6 illustrates apparent seasonal trends. It indicates that urban runoff concentrations in the fall are appreciably lower than the rest of the year. Fall concentrations of COD and solids are shown to be less than half of the summer concentrations. The fall concentrations of other pollutants are shown to be approximately 70 percent of their summer values.

TABLE 5-3. DUNCAN'S MULTIPLE RANGE TEST ($\alpha = 0.05$)

	Zone					Season			Rainfall			Land Use					
	NE	MA	MW	HP	NW	Spr.	Sum.	Fall	Low	Med.	High	Com.	Mix	Res.	Park	Ind.	All Data
COD (35%) 671	82 60 B	46 104 D	61 318 C	143 56 A	40 131 D	56 168 B	73 352 A	38 5 C	67 376 A	51 241 B	49 54 B	112 38 A	66 328 B	49 282 B	37 16 B	71 7 A/B	59
TSS (37%) 746	58 63 D	49 148 D	77 355 C	240 55 A	102 133 B	85 191 A	98 381 A	46 174 B	77 413 A	82 269 A	80 64 A	64 38 NB	78 379 A	6 305 A	46 16 B	73 8 A/B	79
TP (29%) 693	.25 60 C	.33 130 B	.20 314 D	.50 56 A	.21 133 C/D	.24 166 A	.27 381 A	.20 166 B	.25 365 A	.24 266 A	.22 62 A	.19 38 C/D	.24 336 B/C	.27 295 B	.13 16 D	.47 8 A	.24
Pb (37%) 645	.19 157 A	.15 94 A	.15 305 A	.17 56 A	.16 133 A	.17 166 A	.18 345 A	.11 144 B	.19 367 A	.12 220 B	.11 58 B	.17 38 A/B	.18 356 A	.14 235 B	.01 13 C	.09 3 B	.15
Cu (50%) 269	.079 54 A	.031 94 B	.026 60 B	.031 56 B	- - -	.03 65 B	.044 146 A	.026 58 C	.038 148 A	.035 92 A	.037 29 A	.062 37 A	.038 125 B	.032 94 B	.016 10 B	.041 2 B	.037

Variable (Constituent)

(%) % of variance explained

XXX Number of events

1 Best estimate of population median (also geometric mean)

2 Number of events

3 Class

TABLE 5-4. DATA SET ATTRIBUTES BY ZONE

	Zone						
	North East	Mid Atlantic	Mid West	High Plains	North West	Austin Texas	Totals
Number of Projects	3	2	4	1	1	1	12
No. of sites	8	8	9	9	2	2	38
No. of comm. sites	2	0	0	1	0	0	3
No. of resid. sites	3	6	4	5	2	2	22
No. of ind. sites	0	0	1	0	0	0	1
No. of park sites	2	0	0	1	0	0	3
No. on mixed sites	1	2*	4**	2	0	0	9
No. of events	71	138	77	64	133	22	505
No. of spring events	4	73	8	3	49	8	145
No. of summer events	47	16	46	61	33	14	217
No. of fall events	20	49	23	0	51	0	143
No. of low rain events	32	57	14	36	78	7	224
No. of med. rain events	24	56	60	25	48	11	224
No. of high rain events	15	25	3	3	7	4	57

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* by default, project data not available

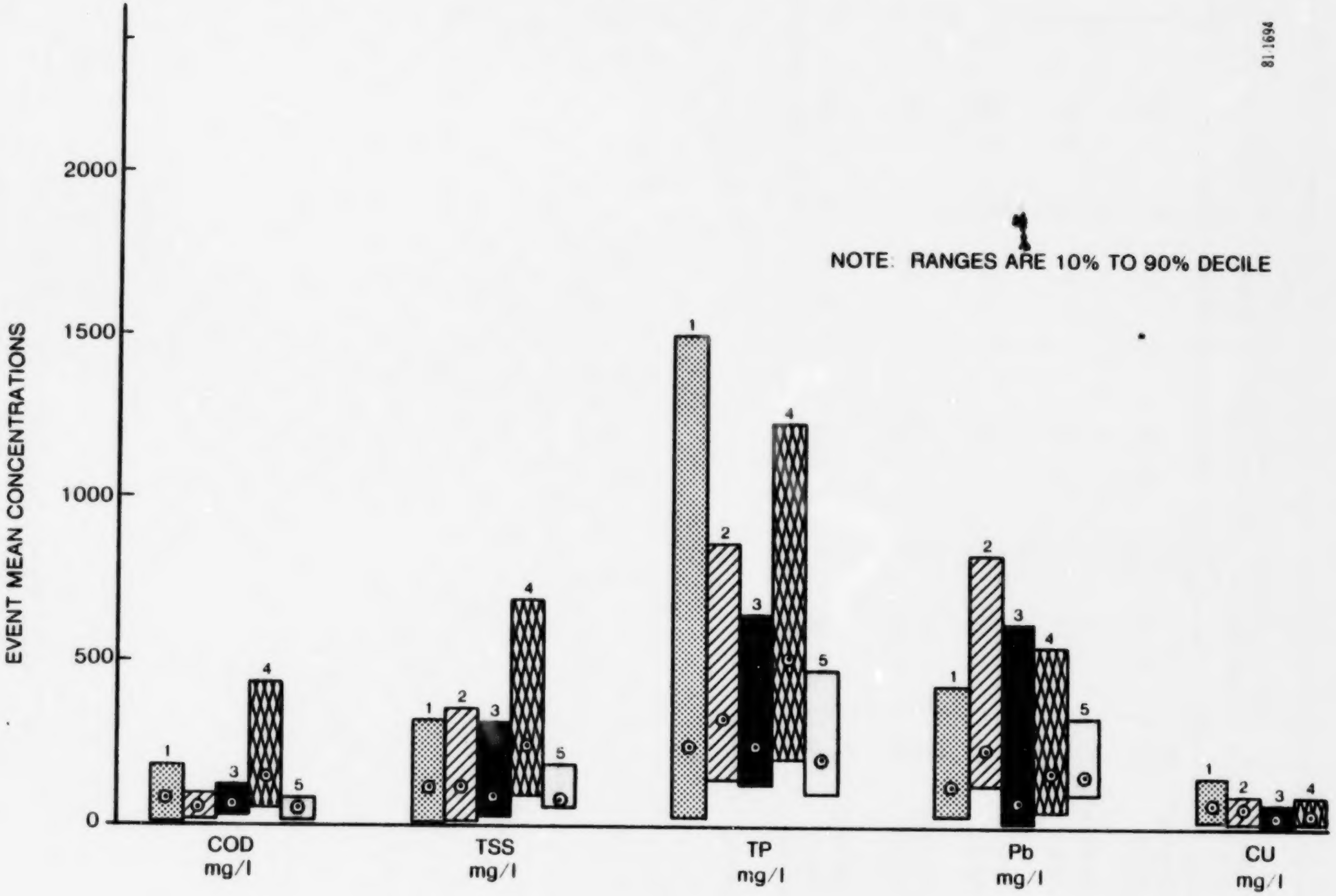
** two by default, project data not available

Values are those in the NURP data base in September, 1981.

TABLE 5-5. DATA AS A RATIO OF TOTAL POPULATION MEDIAN BY ZONE

Const	Population Statistics*	Zone				
		Northeast	Mid-Atlantic	Midwest	High Plains	Northwest
COD	median 59 mean 82	1.39	0.78	1.03	2.42	0.68
TSS	median 79 mean 167	0.73	0.62	0.97	3.03	1.29
TP	median .24 mean .40	1.08	1.38	0.83	2.08	0.88
Pb	median .15 mean .26	1.27	1.00	1.00	1.13	1.07
Cu	median .037 mean .063	2.32	1.91	0.76	0.91	-

* Expressed in mg/ℓ



NOTE: RANGES ARE 10% TO 90% DECILE

Figure 5-5. Zonal Differences in Event Mean Concentrations

TABLE 5-6. DATA AS A RATIO OF TOTAL POPULATION MEDIAN BY SEASON

Constituent	Population Statistics*	Season		
		Spring	Summer	Fall
COD	median 59 mean 82	0.95	1.24	0.64
TSS	median 79 mean 167	1.07	1.24	0.58
TP	median .24 mean .40	1.00	1.12	0.83
Pb	median .15 mean .26	1.13	1.20	0.73
Cu	median .037 mean .063	0.89	1.19	0.70

* Expressed in mg/ℓ

Table 5-7 illustrates apparent trends in rainfall quantity. It indicates that the larger the event, the cleaner the runoff, with concentrations for evenness (over one inch), except for copper which is shown to be somewhat above average. By contrast, low rainfall events (under 0.3 inch) are shown to have higher than average concentrations for all water quality constituents examined.

Table 5-8 illustrates apparent trends in land use. It indicates that the runoff from urban park and open space areas have had significantly lower concentrations than other land use types (as might be expected). For example, heavy metals from park areas are shown to be only about one-third of the average values shown for other land uses. The runoff from residential areas is shown to have generally average concentrations, while that from mixed land use areas is up to 50 percent higher for all constituents examined.

Similar, but more extensive and more definitive evaluations will be made as the data base grows and should permit either of the following conclusions to be drawn.

- Where data are determined to fit a single population or several populations whose differences are relatively small (say ±20 or 25 percent), it may be concluded that there is no practical difference for purposes of evaluations and decisions based on water quality effects. The total population characteristics (mean, standard deviation, etc.) can be used in assessments.

- Where data are determined to be associated with several distinct populations (i.e., where each can be related to the overall population by a particular characteristic such as land use, region, season, or the like), there will be a quantitative basis for estimating local values based on the total population.

Once all NURP data are in the data base and analyzed, the data can be arrayed in any of several formats. NURP has not finally decided which of several possibilities will be the most useful format, given the principal purposes for which the data will be employed. However, NURP is presently inclined toward using the following:

- The basic data listing for all contaminant concentrations and mass loads will be arrayed into a single listing, representing a summary of the pooled data from all monitoring sites in the program representing end-of-pipe urban runoff.

- A series of tables will be developed providing factors based on region, land use, season, or other pertinent influences. These factors will provide the basis for converting the basic concentration and loading values to expected values based on local conditions - whether region, land use distribution, rainfall patterns, or whatever factors are demonstrated by the analysis to be pertinent.

- An example analysis will be developed, illustrating the application of the procedure for the usual situation, that is where

TABLE 5-7. DATA AS A RATIO OF TOTAL POPULATION MEDIAN BY RAINFALL

Constituents	Population Statistics*	Rainfall		
		Low	Medium	High
COD	median 59 mean 82	1.14	0.87	0.83
TSS	median 79 mean 168	0.97	1.04	1.01
TP	median .24 mean .40	1.04	1.00	.92
Pb	median .15 mean .26	1.27	0.80	0.73
Cu	median .037 mean .063	1.03	0.95	1.00

* Expressed in mg/ℓ

TABLE 5-8. DATA AS A RATIO OF TOTAL POPULATION MEDIAN BY LAND USE

Constituent	Population Statistics*	Land Use				
		Commercial	Mixed	Residential	Park	Industrial
COD	median 59 mean 82	1.90	1.12	0.83	0.63	1.20
TSS	median 79 mean 167	0.81	0.99	1.09	0.58	0.92
TP	median .24 mean .40	0.79	1.00	1.12	0.54	1.96
Pb	median .15 mean .26	1.13	1.20	0.93	0.07	0.60
Cu	median .037 mean .063	1.68	1.02	0.86	0.43	1.11

* Expressed in mg/ℓ

adjustments should be made for a number of factors (e.g., region, land use).

- Using the available data base, verification tests will be made to define the reliability of such projections.

This approach is presently favored for the following reasons. All projects would be able to work from the same basic data source. There would be one starting point, rather than many. The tables of factors would show at a glance the relative significance (for any particular pollutant) of regional, land use, and other influences. It may prove to be the most reliable way of incorporating a number of factors and interactions (land use distribution and geographic zone) and the least prone to error or confusion.

PRIORITY POLLUTANTS

Preliminary findings of the program coordinated by EPA's Office of Water Regulations and Standards (OWRS), monitoring for priority pollutants in urban runoff at selected NURP project sites, are presented in the text of the report which is reproduced as Appendix F. All findings and conclusions are considered tentative until completion of thorough quality assurance review.

Our brief summary of some of the salient points in the findings reported is presented below, together with a tentative evaluation of the implications of the preliminary results, in terms of the extent to which priority pollutants in urban runoff are likely to represent a significant threat to beneficial uses.

More than half of the compounds on the priority pollutant list have not been detected in urban runoff in the samples analyzed to date. However virtually all of the heavy metals on the list have been found.

Type Compound	Number Detected	Number Not Detected	TOTAL
Inorganic (Metals)	13	1	14
Organic	49	64	113
TOTAL	62	65	127

Most of those compounds detected, were observed in a relatively small number of the samples. The notable exception to this pattern are the heavy metals copper, lead and zinc, which were essentially always present. A brief summary of the frequency of detection is provided by the following tabulation.

Type Compound	Number in Detection Frequency Range	% of Samples With PP Present	Remarks
Inorganic	3	90 - 100%	Zn, Pb, Cu
	6	20 - 60%	incl As, Cd, Cr, Ni
	4	<10%	
Organic	6	20 - 50%	
	9	10 - 20%	
	34	<10%	

An examination of the raw data currently available indicates that the most appropriate way to interpret the data summaries relative to the frequency of detection (i.e., the percent of the samples where the pollutant was found) is as follows. By and large, at any particular location, a priority pollutant is either generally present in urban runoff or generally absent. Figures for percent of samples which show a priority pollutant to be present can be taken as a rough indication of the approximate percent of monitored locations which have the compound in urban runoff. This will be examined more carefully as additional data become available, however based on the present data base, the following tabulation of several of the detected pollutants indicates the basis for the foregoing preliminary conclusion.

Pollutant (1)	No. of Samples Taken	% of Samples Where Found	% of Site Samples
3	64	25	92
5	64	11	50
23	45	58	65
51	66	24	67
65	68	12	67
66	68	10	50
78	64	34	87
121	67	10	50
Mean	63	23	66

NOTES

1. Code No. for pollutant. See Appendix F for name of compound.
2. For those monitoring sites where the pollutant was found, and where more than one sample was collected, this is the average percent of the samples in which the pollutant was found.

Tentative conclusions regarding the general significance of priority pollutants in urban runoff in terms of potential to cause water quality problems, which are presented below, should be interpreted with the foregoing in mind.

Thus, where a low frequency of detection can be taken as an indication that a general threat to beneficial use is not suggested, one should bear in mind that there may (or will) be a limited number of specific locations where a problem potential exists. Actual concern in such cases would be dictated by the particular use which would be affected by the pollutant and actual use assigned to the local water body.

Heavy metals are the only pollutants suggested by the priority pollutant data base assembled to date to have significant potential for adverse impact on fresh-water aquatic life (based on comparison of observed concentrations with proposed EPA toxic criteria). Fortunately, the routine NURP monitoring effort is accumulating a substantially more extensive data base on metals in urban runoff. These data, together with receiving water analysis procedures which have been adopted, will permit the problem potential of heavy metals to be examined in some depth.

Organic priority pollutants have been detected in urban runoff. However, based on currently available data, it appears that organic priority pollutants do not represent a significant general threat to freshwater aquatic life. Only one compound (pentachlorophenol) has been observed at end-of-pipe concentrations in excess of acute toxic levels according to proposed criteria, and this in only one percent of all the samples taken (a single sample). Chronic levels were exceeded by 4 compounds at occurrence frequencies of 2 to 22%. Given the fact that these are end of pipe values, before dilution in the receiving water, the intermittent nature of runoff, and the relatively low detection frequency, it appears reasonable to conclude that a general concern is not warranted at this time.

Only the heavy metals were detected at concentrations which exceed non-carcinogenic human health criteria for ingestion; no organic priority pollutants were detected at concentrations of concern. As with the freshwater aquatic life beneficial use, the NURP analysis methods, and heavy metal data base will permit the human health issues to be examined further. Although there are a number of mitigating factors, such as stream dilution, reduction by potable water treatment processes, etc., the incidence of certain heavy metals is large enough to warrant further attention, where the affected use is potable water supply.

The remaining beneficial use issue relative to potable water supplies, is the frequency with which potential carcinogens are detected at concentrations in excess of suggested increased risk incidence levels. One metal (Arsenic), and 8 organic priority pollutants fall into this category. The brief examination of detection frequency discussed earlier suggests that the fairly nominal overall frequency of detection would be substantial at some locations.

In attempting a preliminary assessment of the general significance of this class of urban runoff contaminants as a threat to a potable water use, the following tentative observations are made:

(a) The present indications (to be confirmed by additional data analysis) are that pollutants of this class tend to be selectively rather than universally present in runoff discharges.

It is suspected (although not confirmed) that most receiving water segments immediately affected by urban runoff are not used for water supply intakes. It is therefore possible that pollutants of this class do not represent a widespread, general threat to human health.

(b) Where potable water intakes are present within an area of direct influence of urban runoff, it should be recognized that there is a significant problem potential.

WET FALL/DRY FALL

There are insufficient data available to permit analysis in this preliminary report.

Dissolved vs Particulate Forms

An area of concern related to heavy metals in urban runoff is their potentially toxic effects on aquatic organisms. It is the soluble rather than the particulate form that is generally considered to be critical in this regard.

A large data base of heavy metal concentrations in urban runoff has been obtained by the NURP program. While a major portion of such measurements define the "total" concentration (including both particulate and dissolved forms), a significant percentage of the measurements being made determine both dissolved and particulate forms. In addition, the Special Metals data set of the Priority Pollutant Study represents analyses specifically directed at defining the quantities of each form present in the sample.

The data base available from the Special Metals Study is still relatively limited, and the larger data base from the routine NURP monitoring activities has not yet been rigorously analyzed and interpreted. As a result, findings can not be summarized at this time, but will be included in a future update of this preliminary report.

Rainfall and Streamflow

As part of the NURP project and other studies, a large data base of rainfall and streamflow records has been examined. Characteristics which are particularly relevant to this report are summarized below. Rainfall data were analyzed to (1) define the time scales relevant to urban runoff events; and (2) establish the intensity of runoff producing rainfall events. This information is important in developing water quality criteria appropriate to runoff events and in computing receiving water effects for rivers and streams. Streamflow data are also important in evaluating receiving water effects, because of the effect it has on dilution of urban runoff discharges.

Long-term records (10 - 30 years) of hourly rainfall data were analyzed for a total of 33 locations throughout the U.S.. The SYNOP Program was used to compile rainfall statistics (mean and coefficient of variation) for the storm event volume, intensity, duration, and time between storm midpoints.

The average storm duration and time between storm midpoints is summarized in Table 5-9. For the method used in the NURP study to evaluate effect on beneficial use, these are particularly relevant parameters as they indicate, for receiving water organisms, the period of exposure and the time between episodes. Table 5-9 shows that for the eastern part of the country, the mean storm duration is about 6 hours and the time between storm midpoints is about 80 hours. For the semi-arid regions further west the mean storm duration is about the same as the value for the Eastern regions, but the period between events is almost two and one half times longer.

For evaluating receiving water impact, rainfall intensity and stream flow are relevant as noted above. Figures 5-6 and 5-7 portray regional differences for rainfall intensity and streamflow, respectively. As the ratio of average storm intensity to average stream flow increases, so does the potential for urban runoff to create water quality problems. Quantitative relationships between these factors, and problem potential are being developed by the screening analyses being performed.

Summary.

The approach taken for the analysis and interpretation of urban runoff loading data (which produced the results presented above) has been guided by the consideration that problems from contaminants in urban runoff will result, not from their mere presence, but from their magnitude and frequency characteristics.

The basic objective of this type of analysis is twofold:

1. To provide a basis for projecting (with an acceptable degree of confidence) the concentrations and loads of specific contaminants at locations where site-specific measurements have not been made (or where only a limited data set is available). Data limitations can result from situations where only a few storms were monitored at all pertinent land uses or where only some of the land uses in a city were adequately monitored.

2. To provide a basis for examining whether the contaminant concentrations and loads, in a particular location, are likely to cause water quality problems (based on local receiving water characteristics and the desired beneficial uses). Findings relative to this aspect are presented in the following section.

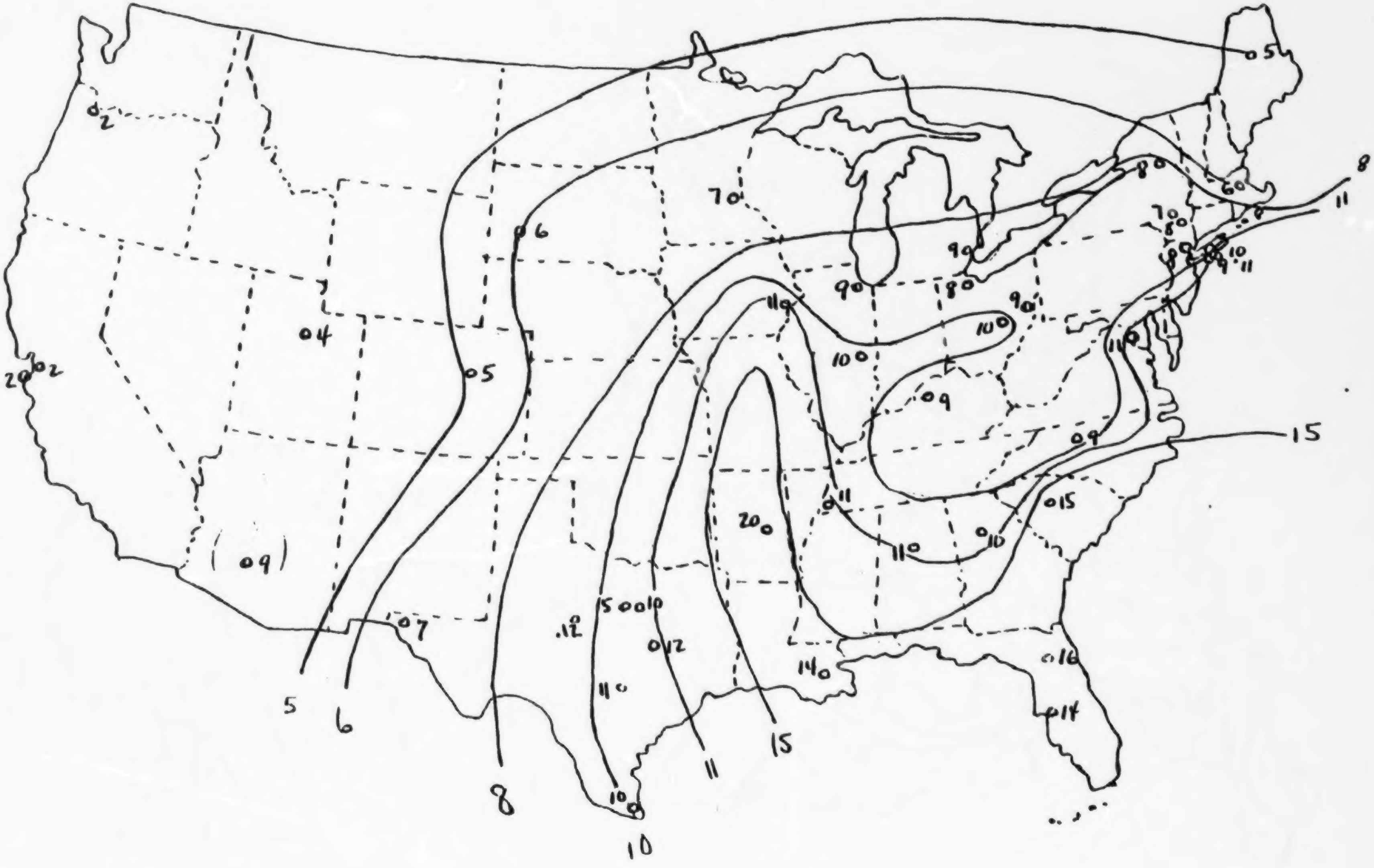
RECEIVING WATER EFFECTS

Introduction.

Only limited quantitative data are currently available to describe the effects of urban runoff on receiving water, and the analysis and interpretation of data from the individual NURP projects have not been completed. Because NURP cannot yet provide even a preliminary analysis of the incomplete data base (as was possible for loads), it has elected to present some "illustrative examples" of receiving water evaluations drawn from selected projects. The interpretations and conclusions presented here should be considered as tentative and may change with additional data or with further analysis and additional reflection on results. The reader should regard the

TABLE 5-9. AVERAGE STORM AND TIME BETWEEN STORMS FOR SELECTED LOCATIONS IN THE U.S.

Location	Average Annual Values in Hours	
	Storm Duration	Time Between Storm Midpoints
Atlanta, GA	8.0	94
Birmingham, AL	7.2	85
Boston, MA	6.1	68
Caribou, ME	5.8	55
Champaign-Urbana, IL	6.1	80
Chicago, IL	5.7	72
Columbia, SC	4.5	68
Davenport, IA	6.6	98
Detroit, MI	4.4	57
Gainesville, FL	7.6	106
Greensboro, SC	5.0	70
Kingston, NY	7.0	80
Lake George, NY	5.4	76
Louisville, KY	6.7	76
Memphis, TN	6.9	89
Mineola, NY	5.8	89
Minneapolis, MN	6.0	87
New Orleans, LA	6.9	89
New York City, NY	6.7	77
Poughkeepsie, NY	6.9	81
Steubenville, OH	7.0	79
Tampa, FL	3.6	93
Toledo, OH	5.0	62
Upton, LI	6.3	81
Washington, DC	5.9	80
Zanesville, WI	6.1	77
MEAN	6.1	80
Beeke, AR	4.9	147
Denver, CO	9.1	144
Oakland, MI	4.3	320
Phoenix, AZ	3.2	286
Rapid City, SD	8.0	127
Salt Lake City, UT	7.8	133
MEAN	6.2	193
Portland, OR	15.5	83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15 00 10
012
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140
016
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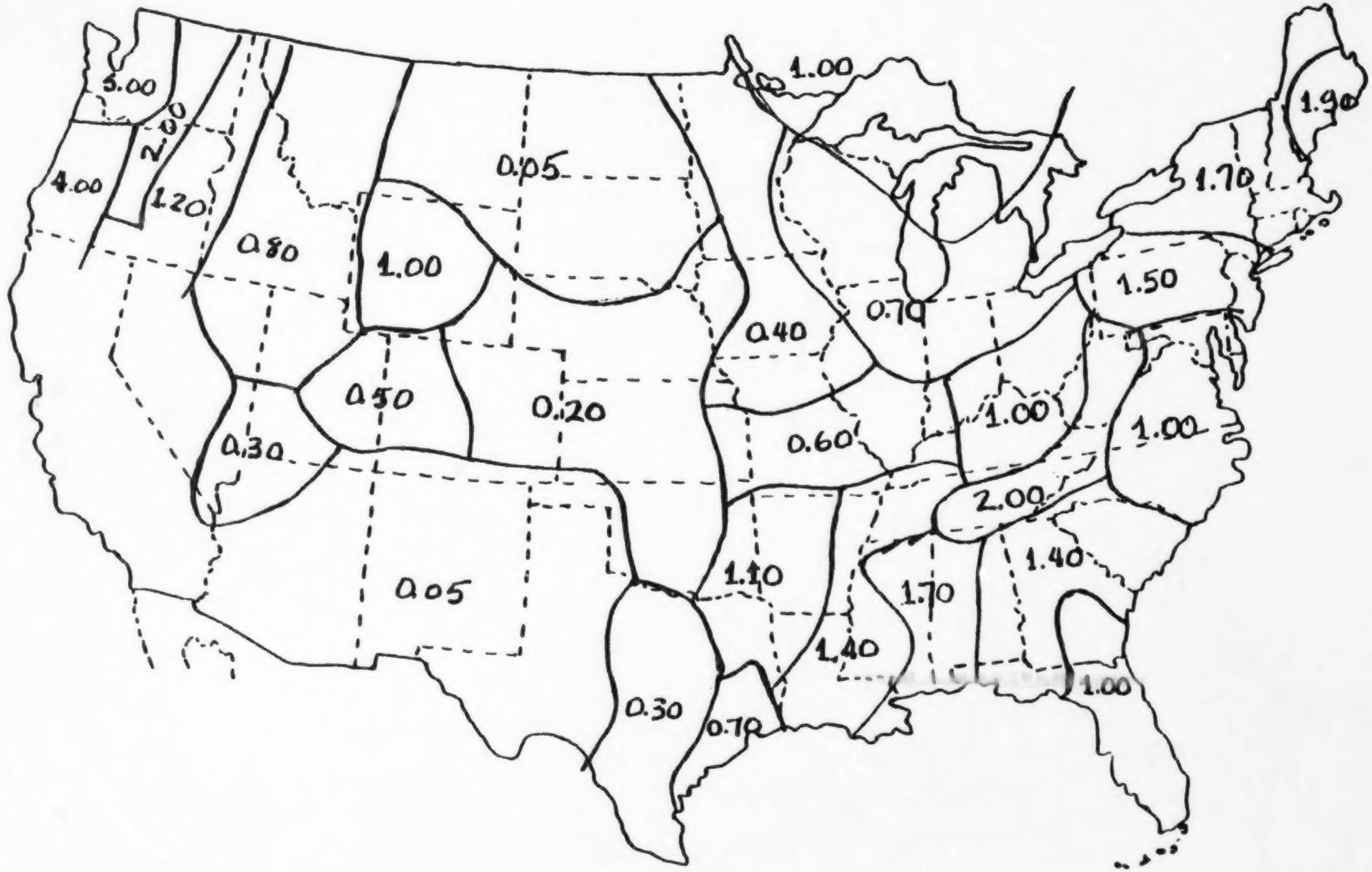
Figure 5-6. Contours of Long Term Storm Event Average Rainfall Intensity For the Period June - September (in/hr x 100)


3.00
2.00
4.00
1.20
0.80
1.00
0.50
0.30
0.05
0.20
0.05
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0.70
0.60
1.10
0.30
0.70
1.40
1.70
1.00
2.00
1.40
1.00
1.50
1.70
1.90
1.00

Figure 5-7. Regional Value of Average Annual Streamflow (cfs/sq mi)

examples as illustrations of an assessment methodology rather than an assessment of the water quality conditions at some site. The principal purpose in presenting the material in this section is to illustrate the approaches being taken and the way results are being interpreted; and less emphasis should be placed on the examples' preliminary findings regarding the nature and degree of effects on receiving waters.

Receiving waters have distinctive general characteristics which depend on type (e.g, stream, lake, estuary) and relatively unique individual characteristics which depend on geometry and hydrology. The approach used here is to proceed from an individual case-by-case basis to the development of broader generalizations (where these will be possible). Given a minimum acceptable amount of data on water bodies and their setting, it appears possible to make useful generalizations regarding the quantitative effects of urban runoff on concentrations of various pollutants in the receiving waters. The frequency of occurrence of various concentration levels which will result (in the receiving water body) from the input of a runoff-borne pollutant can be compared with criteria or standards which are intended to protect various beneficial uses. From these comparisons, we may draw inferences concerning the influence urban runoff may have on these uses.

It is a challenge to interpret data and develop defensible statements regarding the three definitions of a "problem" adopted by NURP. This challenge is described below:

I. Problems Resulting from Denial or Impairment of Beneficial Use. Even if one knows the frequency of occurrence of various receiving water concentrations (resulting from urban runoff), it is difficult to estimate the effect this might have on the particular beneficial uses. This is partly because people may use the water, even when the criteria say it is polluted (or may decline to use it, even when it meets the criteria). This is further complicated by the fact that runoff occurs only a small fraction of the time.

II. Problems Resulting from Violations of Standards. Current water quality criteria and standards were established on the basis of continuous exposure. Notwithstanding administrative decisions which have been made from time to time to interpret such criteria and standards as "never-exceed" values, the fact is that they often represent overly-conservative representations of concentration limits. This is especially likely when receiving water concentrations are intermittent and of a relatively short duration, as is the case with storm runoff effects. Further, for some contaminants (e.g., total suspended solids), there are no corresponding receiving water quality criteria.

III. Problems Resulting from Local Concern. This is potentially the most difficult to deal with formally, because inconsistent interpretations are possible. In some cases, one may find that, although the evidence from I and II above indicate that a particular beneficial use would or would not be feasible, there is either: (a) a lack of local interest in developing or protecting that particular use for that particular water body, or (b) a strong local desire to have a particular use in a particular water body. The willingness of local level decision makers to commit resources or have Federal controls imposed would depend strongly on which of the above local perspectives prevailed.

In another case, one may find that, regardless of quantitative evidence regarding standards violations or use impairment, there are strong subjective local considerations that influence actions one way or the other. In some cases, there may be a reluctance to accept the concept that urban runoff is causing a problem, because there are serious objections to committing local resources (either voluntarily or by government fiat) to that particular problem. This might be likely to occur when it is difficult to reclassify the water body. An opposite example would be where the local citizens desire to find a "problem" associated with urban runoff, because such a finding might make it easier to promote a land use or growth control ordinance.

Quantifying Urban Runoff Impacts on Water Quality.

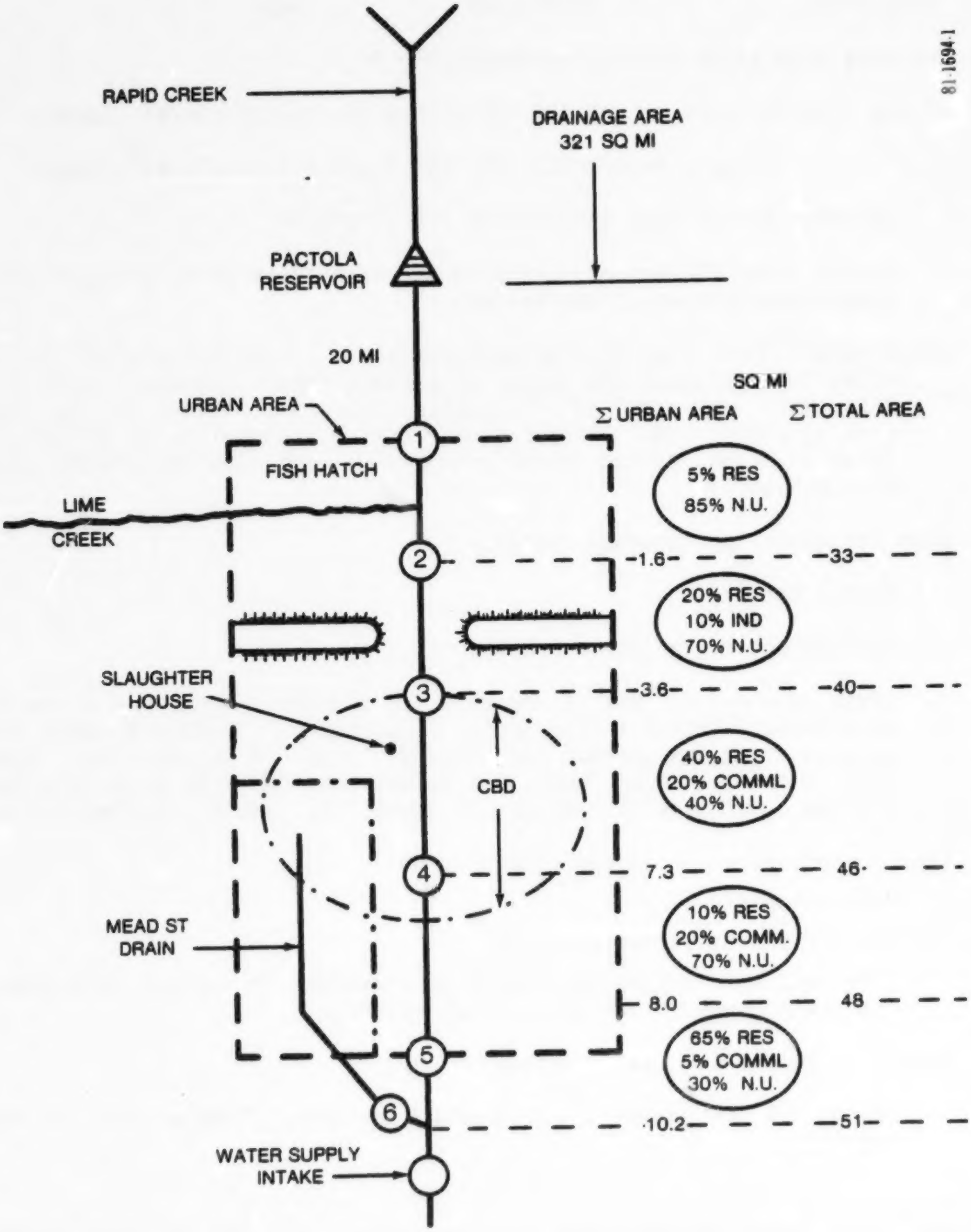
The analysis presented below illustrates the evaluation of water quality effects by application of the screening methodology (described in Chapter 4) and suggests a manner in which results may be interpreted and then used to identify potential problem areas and important follow-up activities.

The example presented here is based on preliminary data developed by the Rapid City NURP project, supplemented by estimates for some parameters for which actual field data are not yet available. Again, it must be stressed that the reader's attention should focus on the methodology illustrated here, not the conclusions, *per se* (since these depend on data which were assumed to apply but were not measured).

Figure 5-8 is a schematic representation of the Rapid City area and its receiving water system. Downstream of the urban area, Rapid Creek supports a warm water fishery and provides potable water for a small community. Early monitoring data indicated relatively high lead concentrations in urban runoff. Since this represents a potential threat to the designated beneficial uses, an analysis was conducted to evaluate the expected effect of urban runoff on Rapid Creek lead concentrations. The objective of the analysis was to determine whether (under the existing combination of local site-specific conditions) the lead from urban runoff is likely to cause sufficiently frequent and high stream concentration intervals to actually impair these uses.

Similar analyses would normally be performed to consider other pollutants of concern.

The format adopted for the analysis utilizes both stream flow and runoff flow expressed in cfs/sq mi, and a Drainage Area Ratio (i.e., the ratio between the upstream basin area contributing to the stream flow and the urban area) as a means of applying the method to a variety of areas, and a means of comparing results.



RAPID CREEK
DRAINAGE AREA 321 SQ MI
PACTOLA RESERVOIR
20 MI
URBAN AREA
SQ MI
Σ URBAN AREA
Σ TOTAL AREA
1
FISH HATCH
LIME CREEK
5% RES
85% N.U.
2
-1.6-
-33-
20% RES
10% IND
70% N.U.
SLAUGHTER HOUSE
3
-3.6-
-40-
CBD
40% RES
20% COMML
40% N.U.
4
7.3
46
MEAD ST DRAIN
10% RES
20% COMM.
70% N.U.
8.0
48
5
65% RES
5% COMML
30% N.U.
6
10.2
51
WATER SUPPLY INTAKE
81-1694-1

Figure 5-8. Schematic of Rapid City Stream System

upstream drainage area = 410 to 460 sq mi
urban area = 10.2 sq mi
from area maps

Drainage Area Ratio (DAR) = approximately 44

stream flow (34 year record Sta. 1) = 39.6 cfs = 0.10 cfs/mi^2 (mean)

(41 year record Sta. 3) = 61.7 cfs = 0.14 cfs/mi^2 (mean)

assumed* annual mean stream flow = 0.12 cfs/mi^2

assumed* coefficient of variation = 2 to 4 (from prior analysis of comparable streams in the region)

Urban runoff flow rate (during mean storm) = 3.1 to 7.7 cfs/mi^2 (Estimated from calculations based on percent imperviousness, runoff coefficient, area rainfall characteristics, population density, and size of urban area. Values show range of uncertainty in estimates. These will be refined based on rainfall and flow monitoring data from project.)

Lead concentration in urban runoff:

Mean = 552 μg/l

Coefficient of Variation = 1.04

(From analysis of monitoring data for 6 storm events at Station 6, Mead Street Drain). For this illustration, Station 6 data are assumed to be representative of runoff from the entire city. Concentrations are about twice the values from the NURP pilot data set and may change with subsequent monitoring results in Rapid City.

Lead concentration in stream (background):

Mean = 4 μg/l

Coefficient of Variation = 0.5

(The mean was estimated from 4 observations in current data base. The coefficient of variation is an estimate.)

Number of storms per year (average) = 101.

(Based on an analysis of rainfall records, from a city in the region).

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* These could later be confirmed through further analysis of local hydrologic records, but the assumed values are probably accurate enough to help illustrate the analytical methodology.

These site conditions were used in the screening methodology. Two sets of calculations were made, using alternate values of the two parameters for which only estimates were available. The results were as follows:

- Figure 5-9 presents the probability distribution of lead concentrations in the stream below the urban area, during runoff periods associated with storm events. The median lead concentration during wet weather is 95-145 μg/l, and 90 percent of the storm events would result in average/concentrations of 450 to 550 μg/l or less. Ranges are presented for these values and indicated by Figure 5-9 to reflect the sensitivity analysis performed because of the uncertainty in several of the input parameters.

- The fraction of the total time that runoff events would be in progress was estimated from the rainfall records and runoff records as follows:

  6.44 hr = average duration of a rain event (from analysis of rain gauge records)

  10 hr = calculated average duration of a runoff event

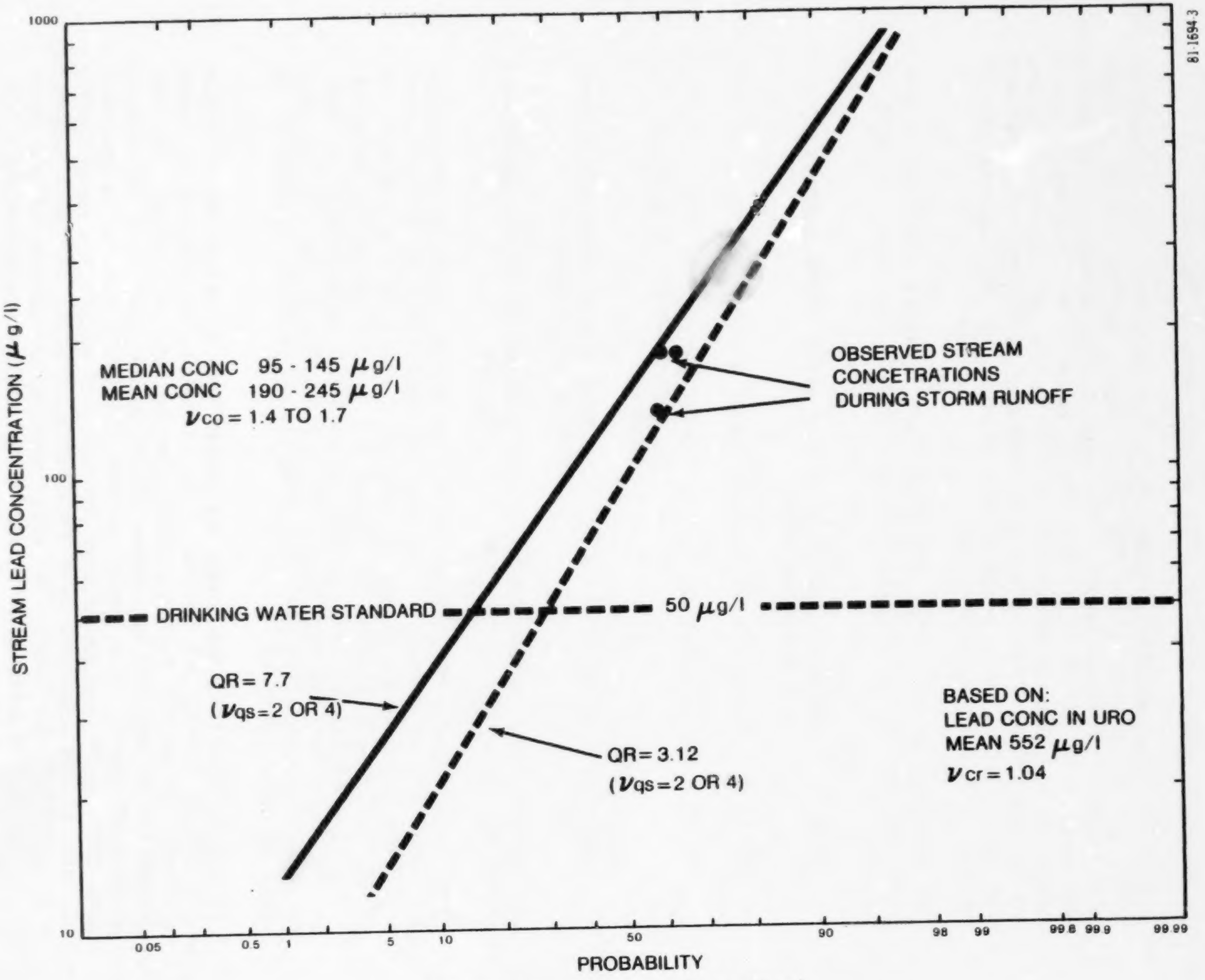
  10 hr x 101 storms/year = 1,010 hours/year = the time during which storm runoff is in progress

  $$\frac{1010}{365 \times 24} = 11.5\% \text{ of the time} = \text{the time during which the stream carries urban runoff}$$

  The stream lead concentration would presumably be at background levels the remainder of the time (i.e., 88.5%).

- Three measurements of lead in the stream during storm runoff periods are available at present. They are not sufficient to define a distribution of observed values to provide a check on the analysis results. They are plotted on Figure 5-9 for illustrative purposes. The most that can be said at present (without speculating) is that, by falling near the middle of the distribution, they do not discourage the assumption that the analysis projections reasonably reflect actual conditions.

Figure 5-10 was derived from the foregoing probability distribution of stream lead concentrations during wet weather. It presents the effects of urban runoff in a more convenient form for evaluation and interpretation. By combining information on the average number of storms per year with information on the percent of storms which cause various concentrations to be exceeded (from Figure 5-9), NURP computed a time-frequency of occurrence relationship (expressed here as the expected mean recurrence interval in years between events of a specified magnitude). By superimposing the concentrations which correspond to various problem definitions on the stream concentration scale,



(Percent equal to or less than)

Figure 5-9. Distribution of Lead Concentrations in Rapid Creek During Storm Runoff Periods (Preliminary Projection)

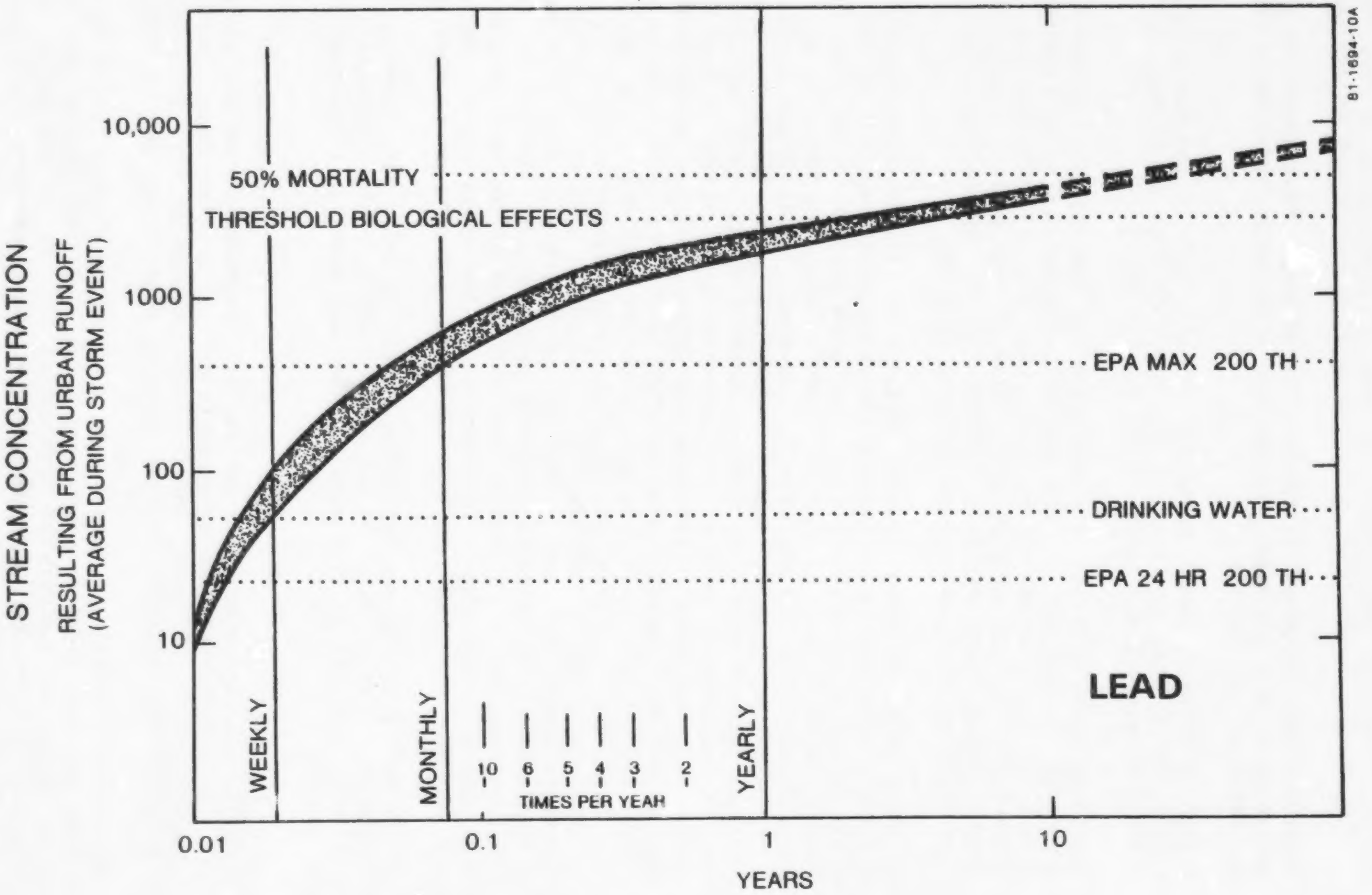


Figure 5-10. Mean Recurrence Interval of Indicated Storm Event Averaged Stream Concentration

we were able to interpret the results in terms of assessments of "problem" potential. The initial indications provided by Figure 5-10 are as follows:

- Regarding EPA proposed criteria: The 24-hour limit would be essentially always violated; the maximum would be exceeded about once per month on the average.
- Regarding drinking water criteria: If this were an untreated water supply, violations would occur during 67 percent of storms, or an average of every 0.013 years (about every 5 days).
- Regarding biota effects: The rationale for the indicated values was presented in Chapter 4. The analysis suggests that a threshold effect (i.e., a situation in which some stress would begin to be felt) would be reached once every three or four years. Significant effects which would seriously stress (but not destroy) the population would be expected once every 20 to 24 years.

Conclusions which might be drawn from an analysis of this type are presented below. These are presented to illustrate the methodology's potential use in evaluating the existence or possibility of a problem and for identifying candidate follow-up activities. It should be recognized that there is an inherent factor of safety in the analysis at this stage. Lead in urban runoff appears to be present principally in particulate form or in close association with particulates (approximately 80 percent) whereas it is the soluble form of lead that is typically of concern. In addition, the toxicity of lead depends strongly on the hardness of the receiving water. Neither factor is accounted for in the methodology presented here, but they could readily be incorporated if appropriate local data were to become available. The current analysis is, therefore, conservative (possibly quite conservative). If an analysis of this type should indicate that a potential problem can be dismissed under these conditions, such a decision can probably be made with some confidence (because of the method's inherent conservatism). Otherwise, the analysis could be repeated using more refined estimates of the pertinent factors. The following illustrates a continuation of the above example recognizing these potential shortcomings, but taking current data at face value.

A number of the NURP projects are collecting receiving water data, similar to the type indicated for Rapid City, in the example above. This procedure will be applied to more projects as time permits. One was done for this report to serve as an example.

Drinking Water Criteria.

The 50 μg/l criterion was computed to be regularly exceeded during periods of storm runoff. This criterion is understood to reflect a safety level for continuous exposure. Thus, periodic, short-term exceedance of this prescribed target level could be tolerated without causing significant health risks.

Based on nationwide statistics, storm events which produce urban runoff occur about 100 times per year and are in progress about 10 percent of the time for the nation at large. An analysis of rainfall statistics for the Rapid City area (through SYNOP) indicates that there are 69 storms per year and that it rains 6.3 percent of the time.

Thus, even in a case where all storms would cause temporary violations in the receiving stream, a water supply intake drawing continuously from the stream at a downstream location would detect lead standard violations in only about 10 to 12 percent of the raw water intake samples (assuming that urban runoff were the sole source of the lead).

This could lead one to conclude that relatively infrequent, short-term (i.e., several hours) exceedances of the Drinking Water Standard could be tolerated without violating the basic intent of the criteria. In fact, a review of much information of this type leads us to suggest that exceedances which persist for 6 to 10 hours (the average duration of a storm) and only a few times a year (say 2 to 3) do not, in fact, impair the beneficial use (potable water supply), despite the fact that they do violate the officially established standard.

In the foregoing illustrative example using Rapid City data, the computed frequency with which drinking water criteria would be exceeded (about every 5 days), and the computed magnitude of violations (criteria would be exceeded by a factor of 10 about once a month), suggests a cause for concern. Such analysis would therefore classify discharges of lead by urban runoff as a "problem" - both in terms of violating standards and in terms of impairing beneficial use.

Figures 5-11 and 5-12 extend the analysis to examine the effect that urban runoff controls could have on reducing the likelihood of criteria violation and use impairment. Control methods are not identified; the analysis evaluates the effect of whatever control procedures will reduce the mean runoff concentration of all runoff from Rapid City, by the indicated factor.

Examination of these results indicates that even reductions of 90 percent (which appears to be a formidable undertaking and which might not be realistic) would reduce the frequency of violations from perhaps once per week to about ten times per year. While this would be an appreciable improvement, it does not appear to be proportionate to the magnitude of the effort (and presumably cost) which would be associated with reducing lead discharges by 90 percent. Even more importantly, such controls would help but not solve, the "problem" (if we accept the target of not exceeding two to three violations per year).

Additional data which should be secured to refine this analysis would include information on the hardness of the receiving water, the distribution of lead forms (i.e., particulate vs. soluble fractions) in Rapid City runoff, information on actual concentrations present in the potable water intake, and the performance of the present treatment facilities in reducing whatever lead is present.

It is anticipated that, if such additional data and further analysis confirm these preliminary indications, alternative solutions to the lead problem (other than urban runoff control) would probably be much more cost effective. Such approaches might include relocating the water supply intake or providing appropriate additional treatment of the water supply.

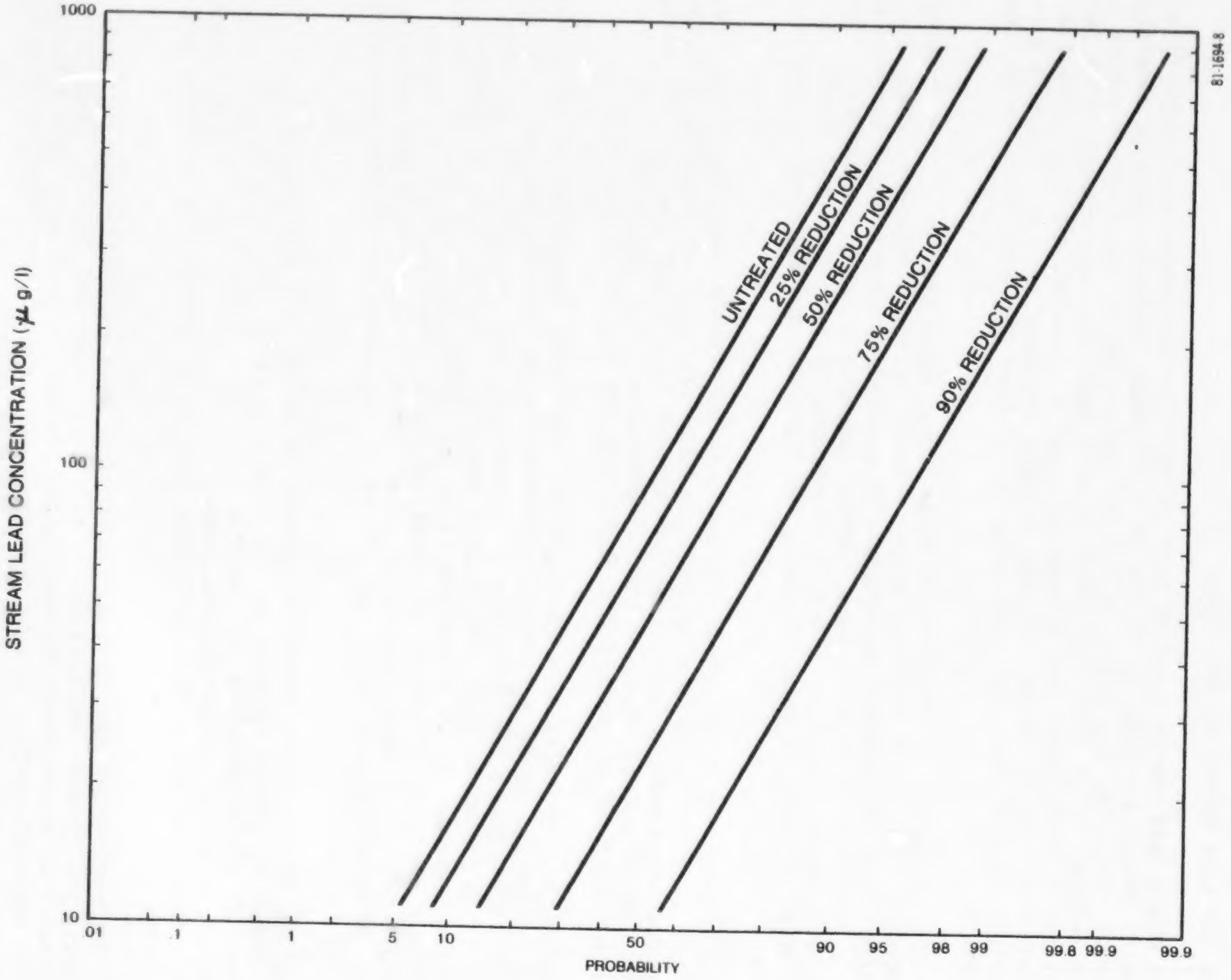


Figure 5-11. Effect of Urban Runoff Control on Distribution of Lead Concentration in Streams

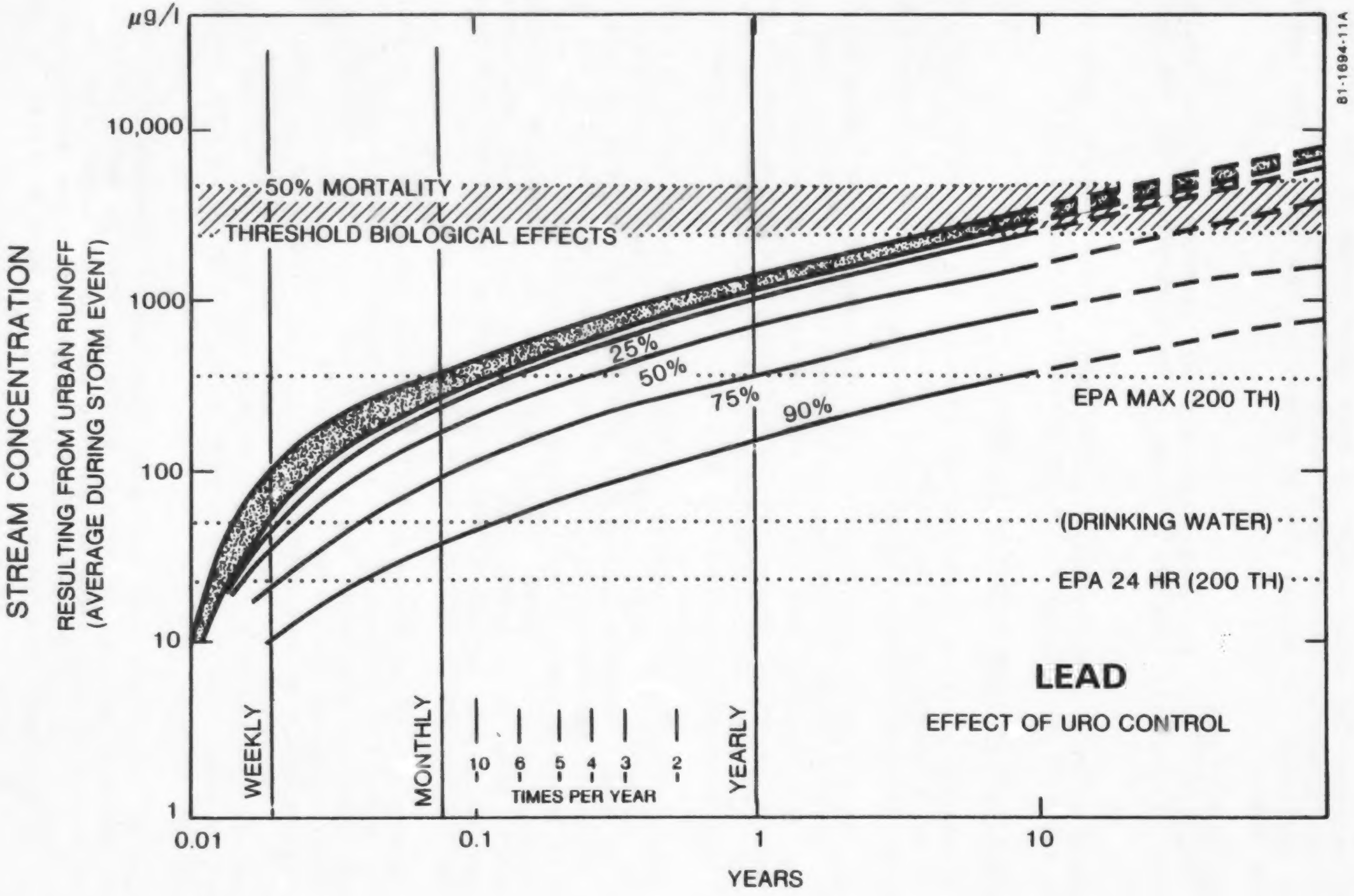


Figure 5-12. Effects of Urban Runoff Control on Lead Concentrations

The first step of further analysis should probably be to determine why the lead concentrations in urban runoff appear to be so high (about twice the values recorded for urban runoff in most other areas of the country). It should be determined whether this pattern continues when additional data become available. It should also be determined how much of the lead is in soluble form.

Biological Criteria

The foregoing type of discussion can be extended to the biological criteria -- probably concluding there to be a marginal, but not serious, effect.

Threshold effects concentrations occur about every 4 years, with serious impact every 20 years or so in limited stream segments.

General Effect Of Urban Runoff On Streams.

The screening analysis technique utilized in the Rapid City example was applied on a broader scale to determine whether any generalized conclusions might be drawn regarding urban runoff impacts over the nation as a whole.

The initial evaluation performed for this draft report, considered only heavy metals. Values used for estimating concentrations of copper, lead, zinc, cadmium, and chromium were derived from other sources, since the required information was not available from the NURP data base at the time the screening was initiated. This preliminary analysis will be updated for the next draft and extended to evaluate other contaminants present in urban runoff.

The results and discussions presented below should be considered illustrative of the approach, the possible effects, and the types of conclusions which might be drawn. Certain indications will very likely change in detail, but NURP suspects that the substance will not. Possible exceptions may be provided by lead and zinc. All of the current analyses utilize total metal concentrations in urban runoff. Lead and zinc (as previously indicated in Table 5-9) tend to be present in the form of particulates, and subsequent analysis using data for the more appropriate soluble fraction could result in substantive changes in conclusions.

The results of the screening analysis performed for copper will be used here as the basis for discussion. Figure 5-13 presents a projection of the expected frequency with which end-of-pipe urban runoff concentrations (before any dilution by the receiving stream) would exceed a variety of target concentrations which reflect either water quality criteria or estimated "effect levels". The basis for the "toxic effects" level shown on these plots is presented in Appendix D. The projections are based on concentrations of copper in urban runoff having a mean concentration of 70 μg/l and a coefficient of variation of 1.07.

Inspection of Figure 5-13 indicates that copper concentrations in urban runoff would be expected to reach or exceed the Drinking Water Criteria level on an average of once every 40 years or so. To the extent that the copper concentrations in urban runoff used in the calculation are representative, it could be concluded that urban runoff would not pose a threat to drinking water sources (based on the criteria for copper).

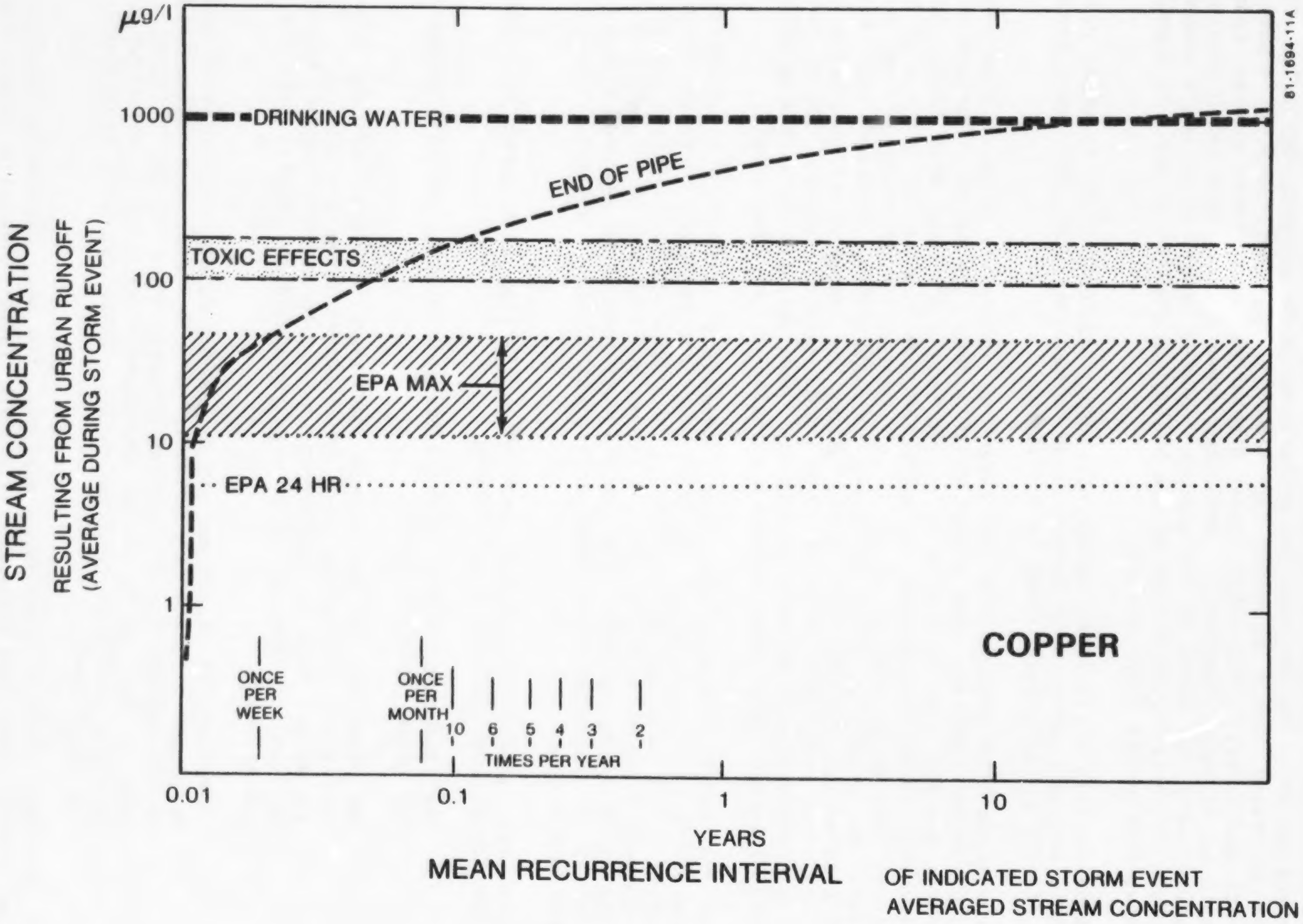


Figure 5-13. Copper Concentration in Urban Runoff

Potential toxic effects on stream biota, are indicated to be quite a different matter. The proposed EPA criteria would be exceeded regularly. Even the estimated levels at which the intermittent, short-duration exposures which would result from urban runoff discharges, would cause adverse impacts would be exceeded frequently. Undiluted urban runoff would reach threshold levels every few weeks on the average. Stress levels which would probably result in mortality of a part of the biological population would be expected about five or six times per year.

Based on this first-order screening, copper concentrations in urban runoff would probably present no threat to drinking water uses, but would present a significant potential threat to a fishery.

In Figures 5-14 through 5-17 the effect of increasing dilution from stream flow can be examined. For a particular stream flow regime, represented by annual average flow in cfs/sq mile, increasing Drainage Area Ratios (DAR) represent increasing degrees of average stream flow at the urban area and, hence, increasing degrees of dilution. Inspection of these figures indicates the extent to which increases in contributing drainage area, for a particular set of conditions, would reduce the frequency of occurrence (increase the recurrence interval) for any particular target. The projected concentration-frequency relationship now represents the in-stream concentrations expected immediately following dilution of the urban runoff.

For the end-of-pipe condition, the frequency of occurrence relationship is due solely to the variability of event mean concentrations of copper in urban runoff. The mean recurrence interval relationship for in-stream concentrations which result from urban runoff (shown by Figures 5-14 through 5-17) are determined by the variability of urban runoff concentrations, and also by the statistical characteristics (mean and variability) of rainfall, runoff flow, and stream flow.

Extensive sensitivity analyses performed utilizing this screening calculation for streams indicate the following:

- The important climatological element is average rainfall intensity - not annual rainfall volume.
- The hydrology of the stream (annual or seasonal average flow in cfs/sq mi) and the variability of stream flows are critical. There are marked regional differences but, even within a region, there can be local differences which are comparable or greater than the regional trends.
- Some types of impact can not be addressed, as in the case of metals, by simple dilution calculations. BOD/DO impacts are influenced both by the variability of instream concentrations of BOD following dilution as well as by stream characteristics (depth, velocity) which strongly influence reaction rates. These can vary considerably at the local level.

On the basis of such sensitivity analyses, the mean recurrence interval relationships shown are presented as a band, rather than as a single line as

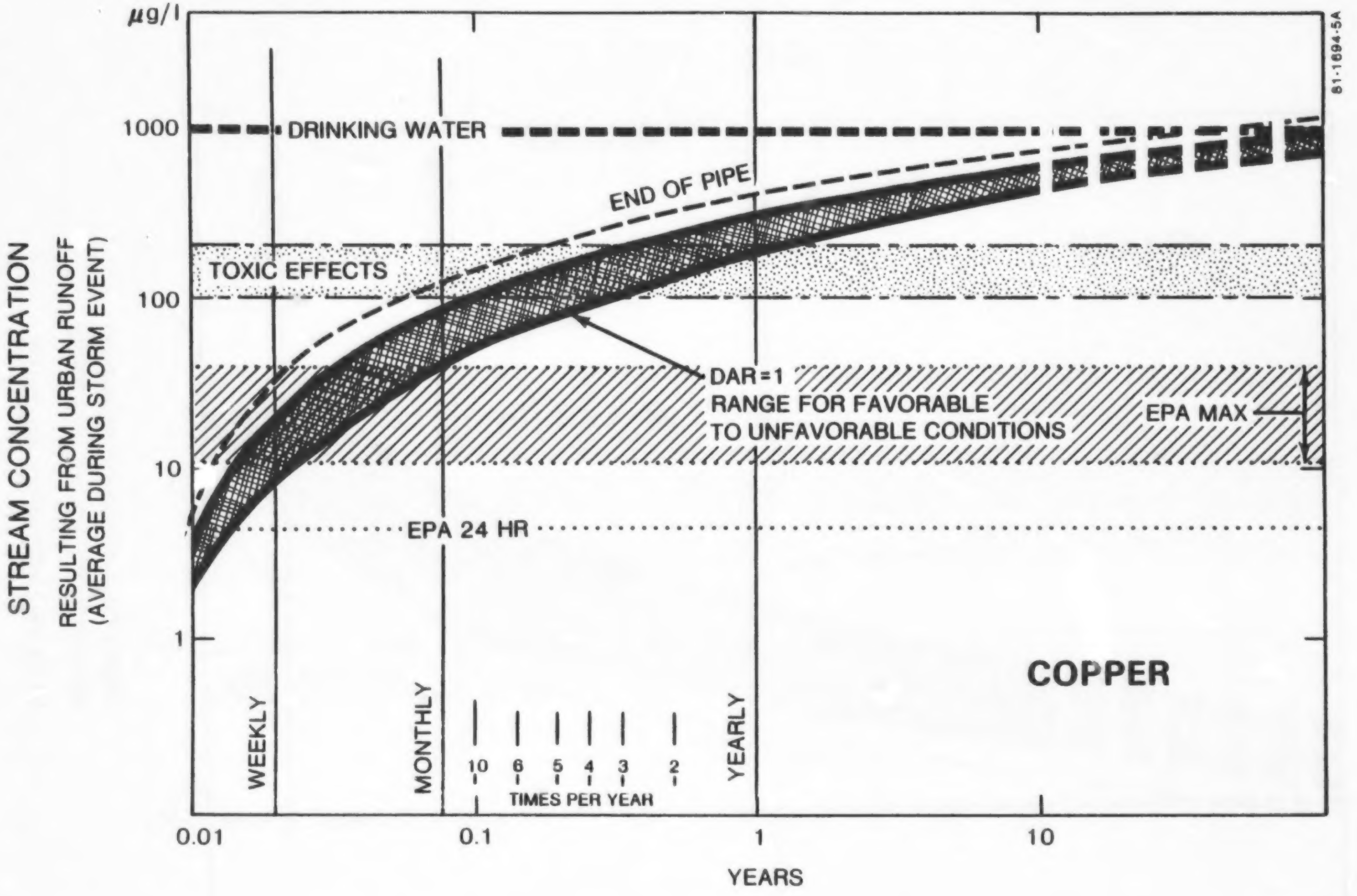


Figure 5-14. Copper - Mean Recurrence Interval of Indicated Storm Event Averaged Stream Concentrations - End-of-Pipe

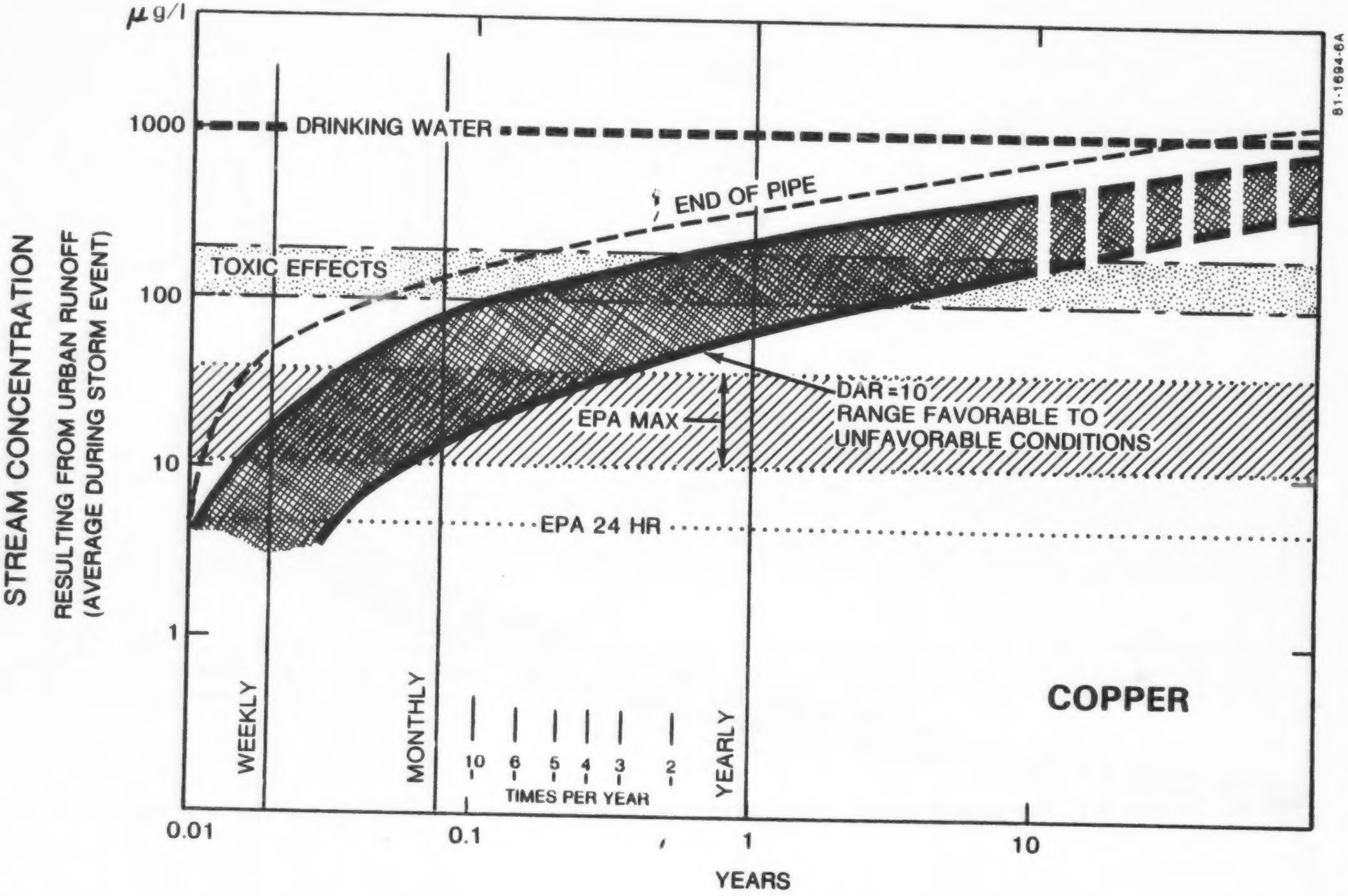


Figure 5-15. Copper - Mean Recurrence Interval of Indicated Storm Event Averaged Stream Concentrations - DAR 10

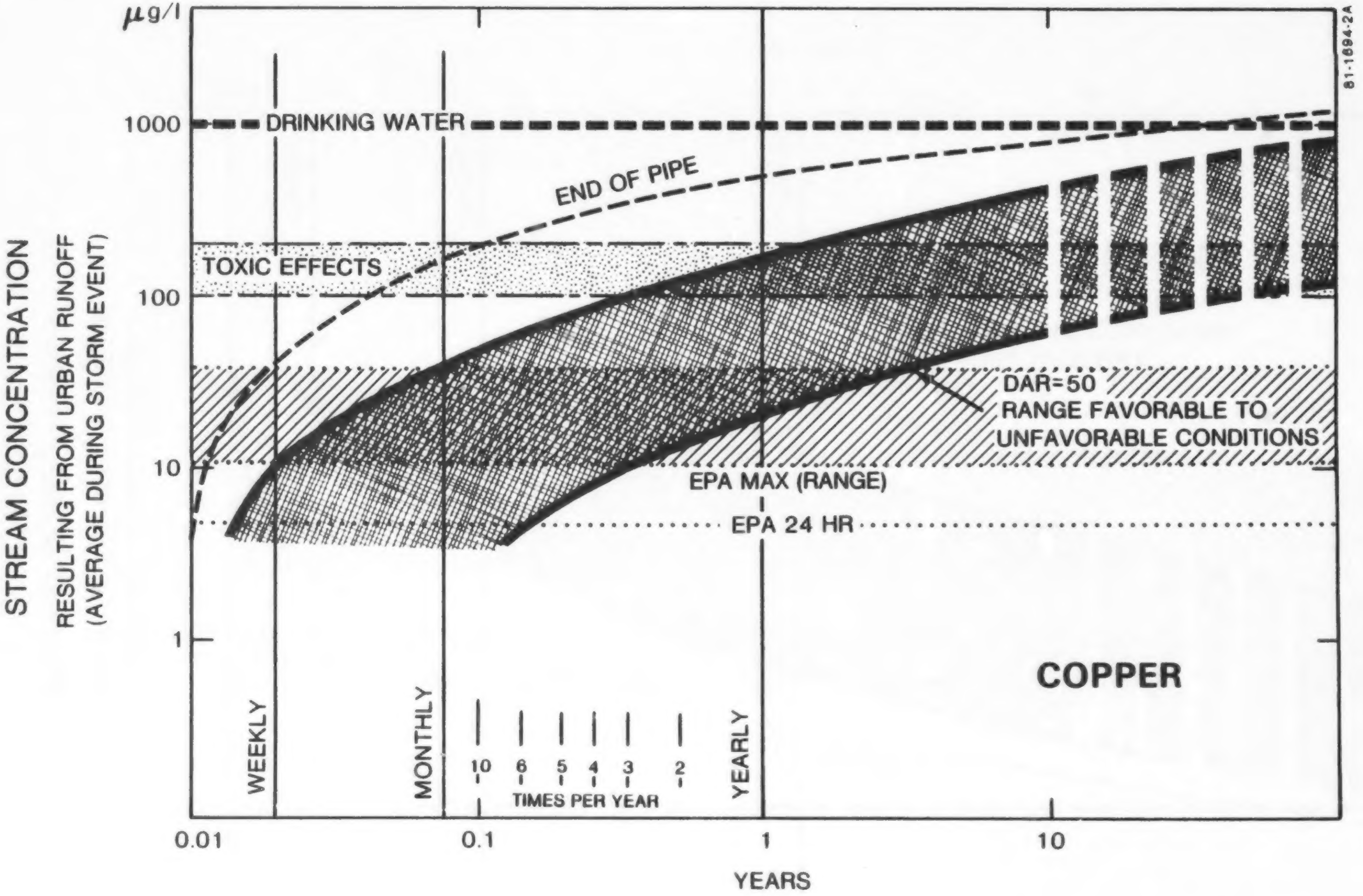


Figure 5-16. Copper - Mean Recurrence Interval of Indicated Storm Event Averaged Stream Concentrations - DAR 50

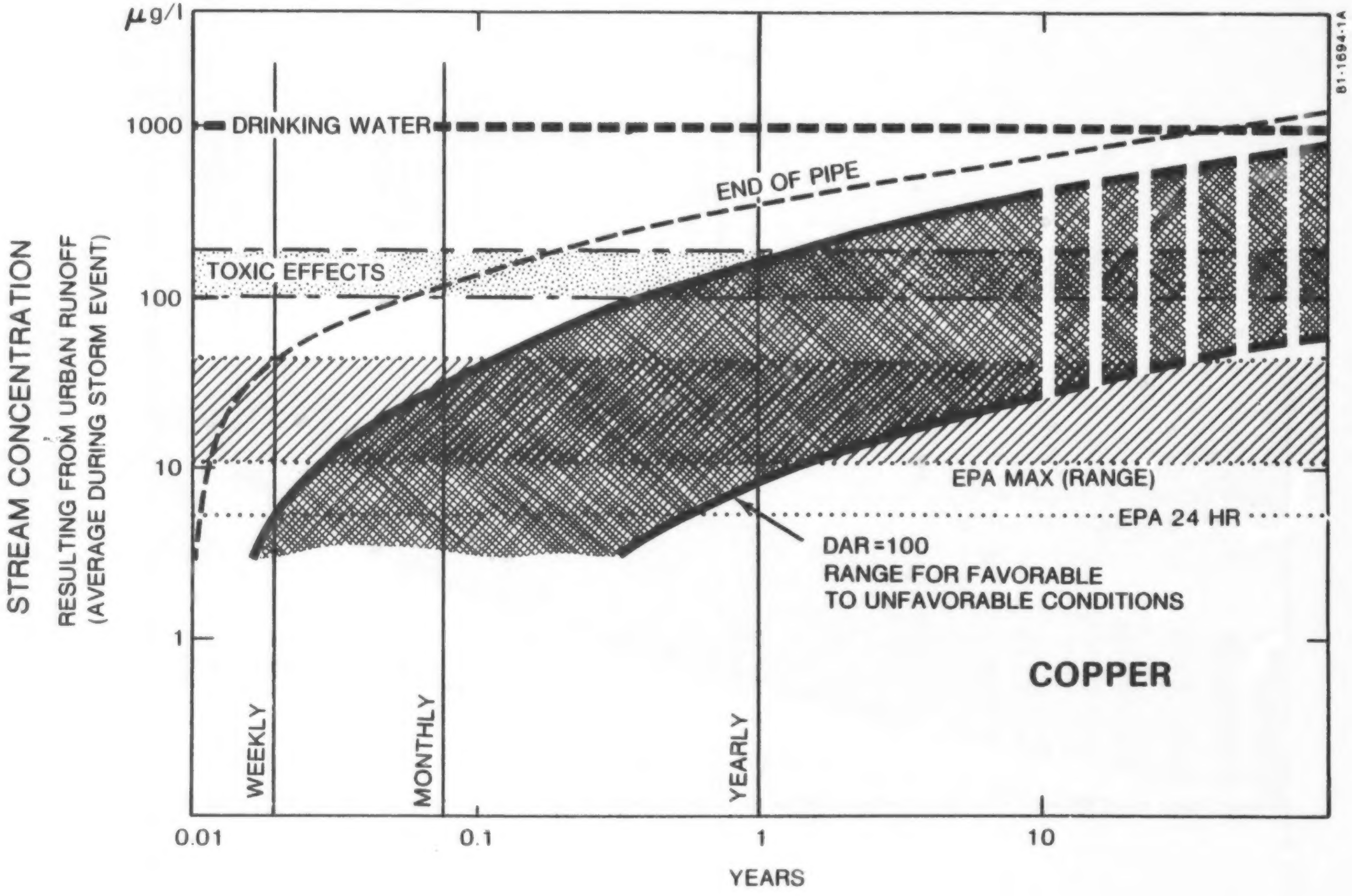


Figure 5-17. Copper - Mean Recurrence Interval of Indicated Storm Event Averaged Stream Concentrations - DAR 100

was possible for looking at end-of-pipe conditions. The upper bound represents "unfavorable" conditions; the lower bound, "favorable" conditions. Basically, unfavorable conditions result from a combination of relatively high average rainfall intensities and relatively low, and variable, stream flows. Higher and less variable stream flows and lower average rainfall intensities in a local area tend to provide more favorable conditions.

The limits selected for this screening analysis were arbitrary but were based on fairly extensive (but not comprehensive) sets of data on rainfall and stream flow characteristics for locations which encompass much of the nation. NURP qualitatively estimates that the bounds selected reflect approximately the upper and lower quartiles of the full range of conditions. Thus, while the range depicted covers a major portion of the range of actual conditions, there will be conditions both more and less favorable in an appreciable number of locations. Rapid City, for example has local conditions which are slightly less favorable than the "unfavorable" end of the range used in the general analysis, due principally to the very low average stream flows which are characteristic of Rapid Creek.

The salient indication provided by a review of the screening results presented by Figures 5-14 to 5-17 is that local rainfall and streamflow characteristics (which are influenced to a significant degree by region, but not totally so) are of much greater significance than drainage area ratio per se, though DAR has an obvious influence. Mean recurrence intervals at which specific effects levels can be expected can vary from frequent to rare, when a broad national look is attempted.

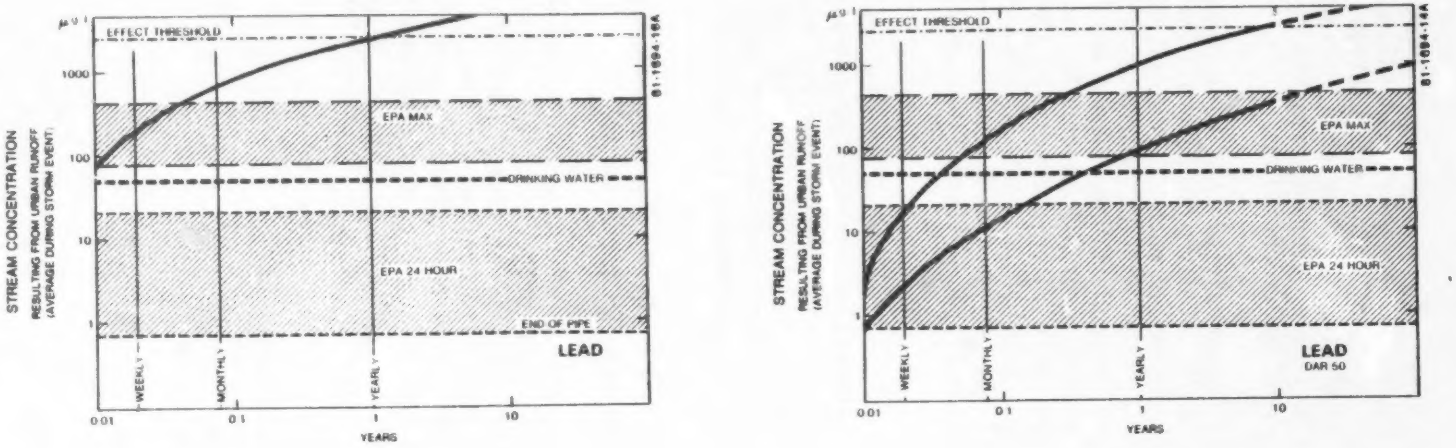
Results of this preliminary screening for other heavy metals are presented in Figures 5-18 (lead), 5-19, (zinc), 5-20 (cadmium) and 5-21 (chromium).

Water quality data in river and stream reaches directly influenced by urban runoff is being secured by 11 of the individual NURP projects in sufficient scope and detail to permit an evaluation of water quality effects. Each project will apply analysis procedures adopted in the individual work plans. In addition, the screening technique described above will be applied by NURP to a number of these project situations for comparison of results and concluions regarding water quality effects of urban runoff. Individual NURP projects with program elements which emphasize water quality impacts in rivers or streams include the following:

Durham, NH
Mystic River, MA
Irondequoit Bay, NY
Baltimore, MD
Tampa, FL
Knoxville, TN
Milwaukee, WI
Champaign Urbana, IL
Kansas City, KA
Rapid City, SD
Little Rock, AR
Denver, CO
Salt Lake City, UT
Bellevue, WA

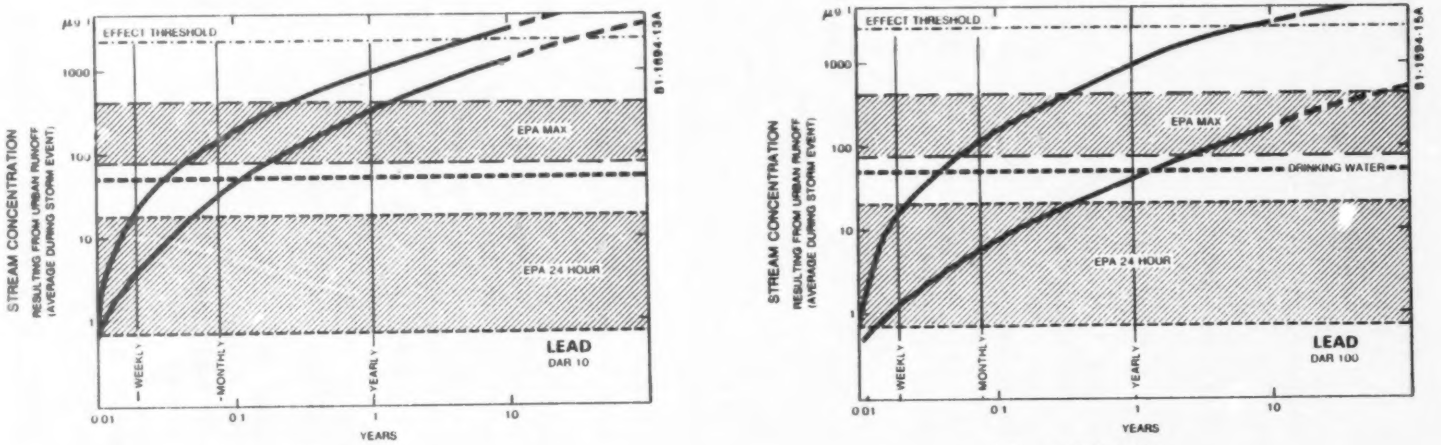
General Effect Of Urban Runoff On Bays And Estuaries.

The effect of urban runoff on the water quality of bays and estuaries is an element of the four individual NURP projects listed below. Local analysis and evaluation of water quality impact data, will be supplemented by the



(a) End of Pipe

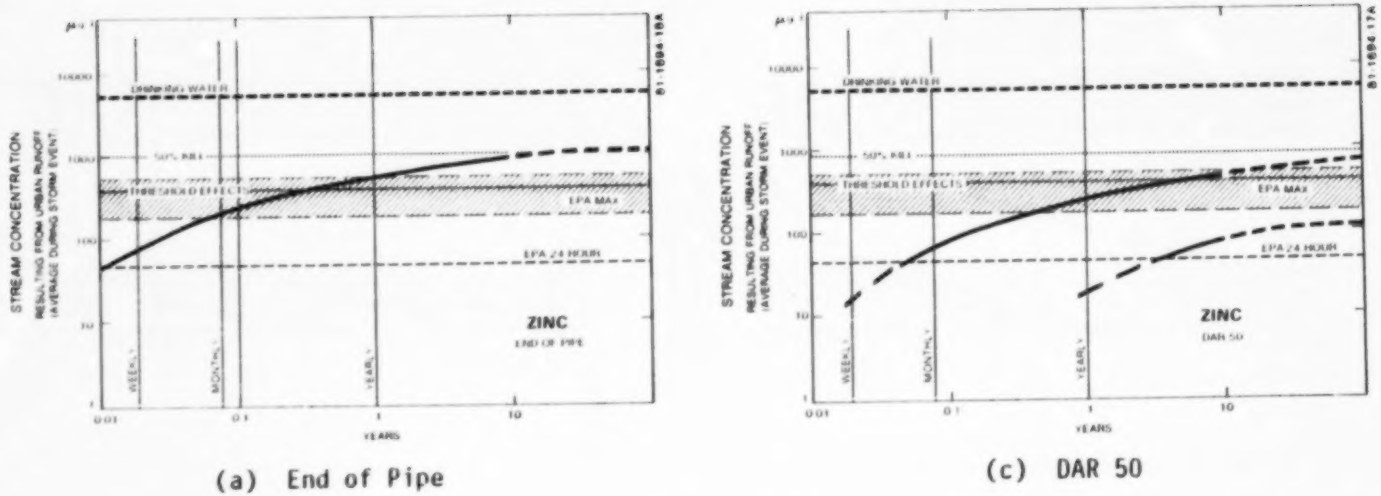
(c) DAR 50



(b) DAR 10

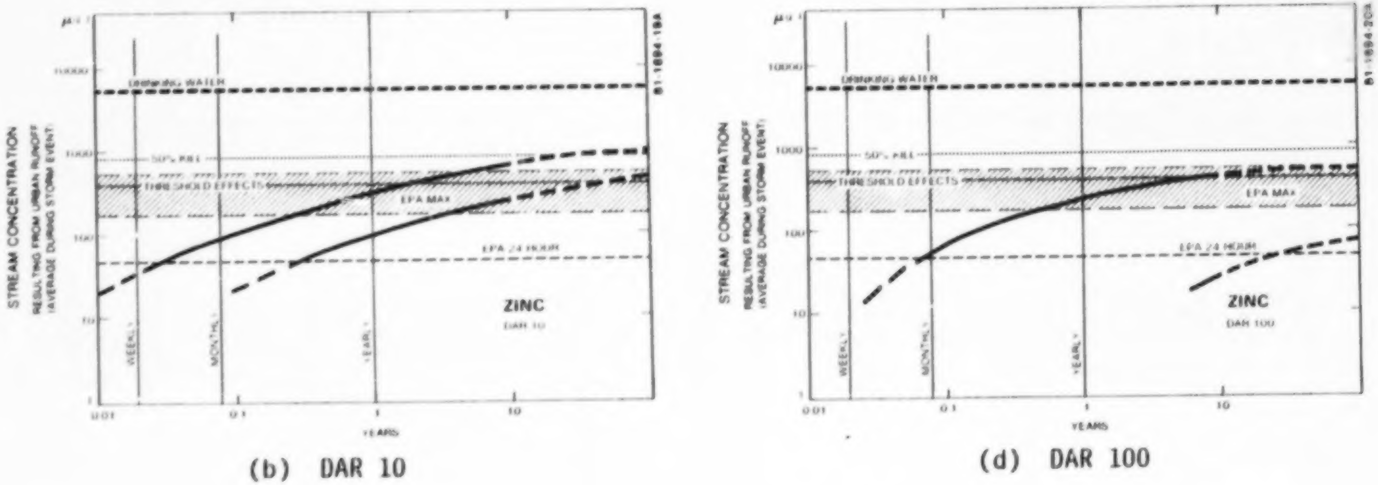
(d) DAR 100

Figure 5-18. Lead-Mean Recurrence Interval of Indicated Storm Event Averaged Stream Concentrations



(a) End of Pipe

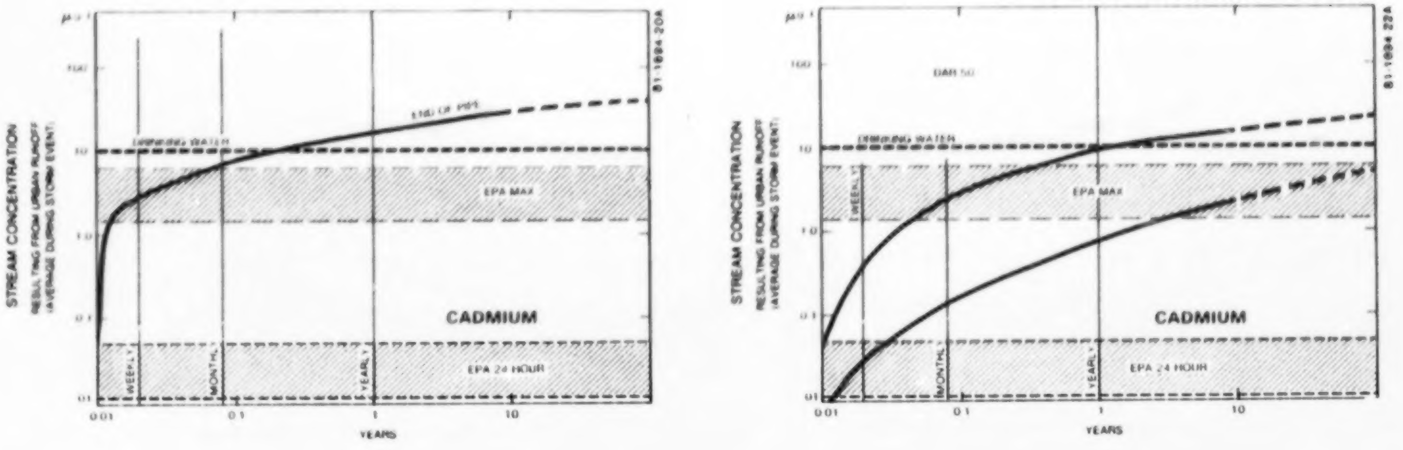
(c) DAR 50



(b) DAR 10

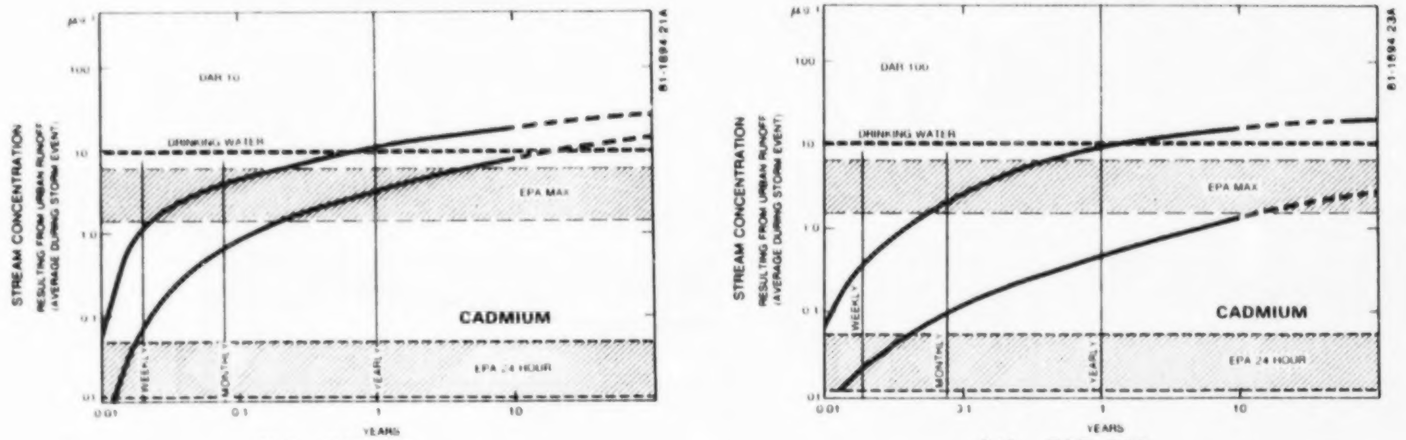
(d) DAR 100

Figure 5-19. Zinc-Mean Recurrence Interval of Indicated Storm Event Averaged Stream Concentrations



(a) End of Pipe

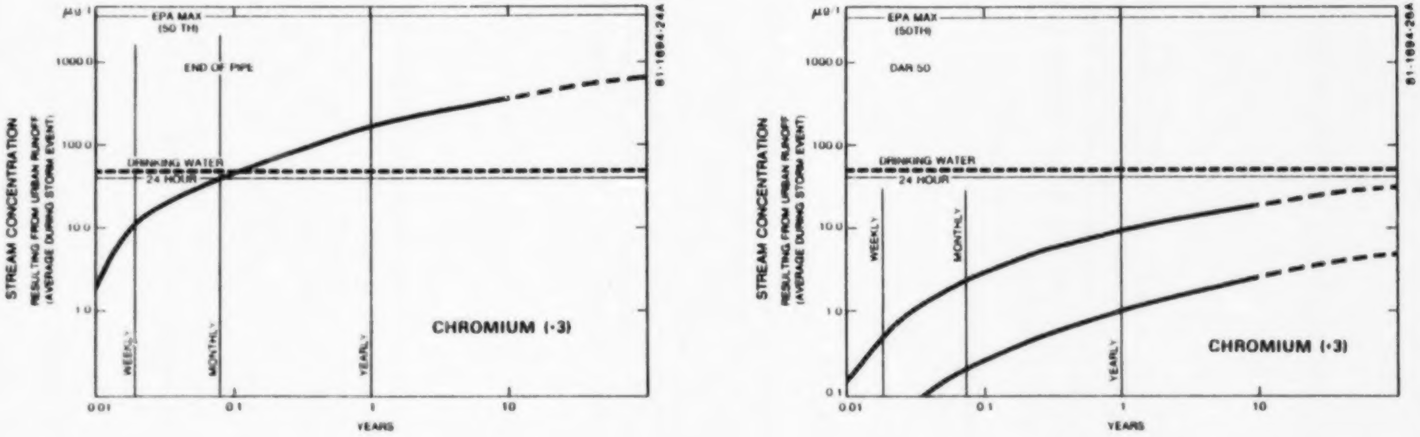
(c) DAR 50



(b) DAR 10

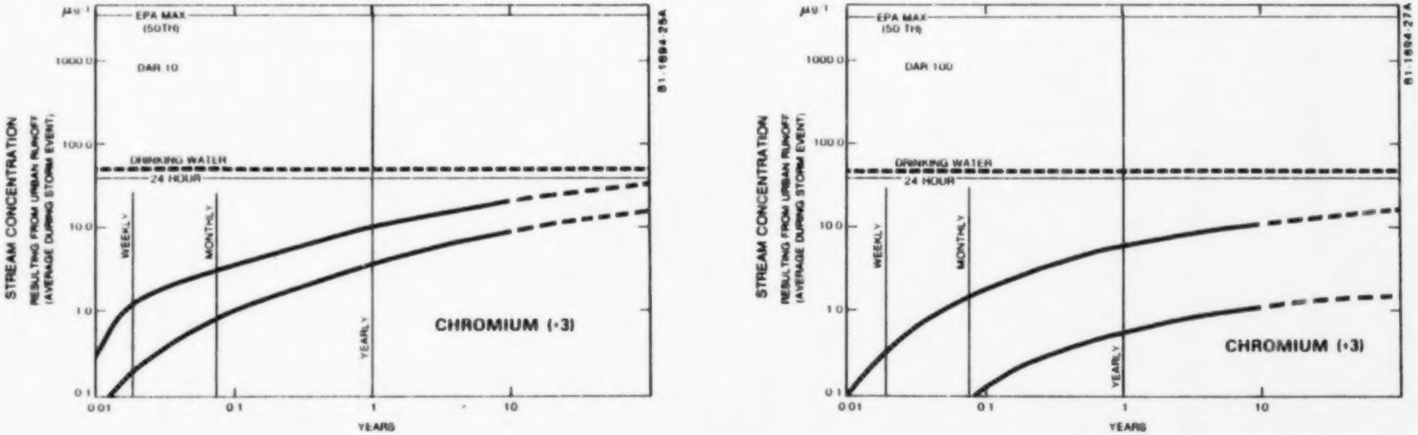
(d) DAR 100

Figure 5-20. Cadmium - Mean Recurrence Interval of Indicated Storm Event Averaged Stream Concentrations



(a) End of Pipe

(c) DAR 50



(b) DAR 10

(d) DAR 100

Figure 5-21. Chromium - Mean Recurrence Interval of Indicated Storm Event Averaged Stream Concentrations

screening method described in Chapter 4, in situations where the system is not so complex as to make the simplified analysis unrealistic (Durham), or where it can be effectively applied to an isolated segment of the system (Long Island).

Long Island, NY
Washington, DC (through coorperation with separate Potomac Estuary Study)
Durham, NH
Tampa, FL

General Effect Of Urban Runoff On Lakes.

Emphasis on the water quality effects of urban runoff or lakes, through monitoring efforts and formal analysis of such data, is an important component of the work plans for the 8 projects listed below. Where practical, NURP plans to apply the screening procedure described in Chapter 4 to compare results with those obtained from local site specific analyses.

Mystic Lake, MA
Lake Quinsigamond, MA
Lake George, NY
Irondequoit Bay, NY
Washington, DC
Chicago, IL
Austin, TX
Denver, CO

General Effect Of Urban Runoff On Groundwater.

Two projects have formal detailed programs to monitor and evaluate the effect of recharge of urban runoff on water quality of groundwater aquifers. Screening analysis type procedures have not been developed at this time for groundwater aquifers. Conclusions with regard to water quality effects will rely on data and analysis from these two projects - but will be supplemented by data from non-NURP locations (e.g., Phoenix, Spokane) to the extent that it is possible for NURP to identify additional sources of such information, and obtain and analyze it.

Long Island, NY
Fresno, CA

EVALUATION OF CONTROLS

One of the main objectives of the NURP effort is to provide information that will lead to implementation of best management practice (BMPs) where warranted to control pollution from urban runoff. A part of the reluctance to implement such controls stems from a general lack of information on their effectiveness. Thus, an evaluation of the performance of selected BMPs is an integral element of NURP. Cost data are also necessary so that benefit/cost analyses can be conducted to facilitate prudent decision-making. However, at the time of this writing cost data from the NURP projects are not available, and the following discussion is necessarily limited to performance effectiveness.

Detention Basins.

The measure that is used here to evaluate control effectiveness is the reduction in event mean concentration.

Ideally, such calculations would be made using synoptic data for a given basin. The pilot data set has only one such detention basin data set at this time, and removal effectiveness data for it are presented in Table 5-10. As can be seen, there is a high degree of variability in the performance of this basin, especially in view of the relative uniformity of rainfall amounts. For example, solids are removed (8 percent to 18 percent) for three events and exported (-36 percent and -44 percent) for the other two.

TABLE 5-10. PERCENT REMOVAL EFFECTIVENESS FOR THE TRAVER CREEK DETENTION BASIN

Event Date	Precip. (in.)	COD	TSS	TP
4/11/81	1.1	35	9	50
4/13/81	1.0	(22)	(36)	33
4/22/81	0.95	4	8	11
5/9/81	1.4	29	(44)	33
6/13/81	1.5	31	18	60

( ) indicates negative values

In order to obtain a preliminary insight into overall detention basin removal effectiveness, pooled influent and effluent data on a site basis were used to estimate average event mean concentrations, and these were used to estimate overall basin performance. There are limited data in the pilot data set that allow such determinations to be made for nine detention basins, and the results are presented in Table 5-11. As can be seen, some detention basins are very effective in removing urban runoff constituents, others have rather marginal performance, and some are quite poor. Of course the negative average removal efficiencies should not be interpreted as implying that a detention basin actually produces the particular constituent in question. It merely indicates that for those particular storm events that were monitored, the effluent concentration on average exceeded the influent concentration. This could occur, for example, if deposition in the basin by unmonitored antecedent events was scoured out by the monitored event. Nonetheless, negative removal efficiencies are indicators of poor basin performance.

In an attempt to determine some indication of overall detention basin performance across the country, the data for all detention basin sites were pooled, and SAS UNIVARIATE runs made on their logarithms for both influent and effluent concentrations. Percent removal effectiveness numbers were then calculated, and the results are given in Table 5-12.

National numbers from the load file are also given, and comparison shows that the detention basin influent data pool is a very reasonable representation of the national level file. Percent reductions are presented for the concentration mean, median (geometric mean), tenth percentile, and ninetieth percent points. Unfortunately, the number of data points in the effluent COD

TABLE 5-11. OVERALL PERCENT REMOVAL EFFECTIVENESS FOR SELECTED NURP DETENTION BASINS

Effluent Site	COD	TSS	TP	Pb	Cu
DC151UR04	-	55	67	-	-
DC151UR11	-	15	5	-	-
DC151UR16	-	94	71	-	-
WOODHOLLOW	59	79	58	-	-
C006711586*	33	(21)	58	(18)	27
C006711637*	(45)	2	(11)	(33)	55
PITTAA	18	27	5	47	80
TRAV CK	20	(3)	37	-	-
LAKE ELLYN**	59	91	56	96	91
( ) indicates negative values					

* These figures represent percent removals before the basins were modified for water quality control.

** Calculation based on SAS UNIVARIATE runs as logs of pooled discrete sample data.

pool is too small to allow this population to be meaningfully represented, and no removal effectiveness numbers cannot be calculated. As can be seen, however, percent removals for the other constituents tend to support the trend observed in Table 5-11.

At this juncture it can be stated that detention basins can be effective in reducing urban runoff concentrations under circumstances where the design (including inlet and outlet structures and size relative to the drainage area) is appropriate for this purpose. On the other hand, there is evidence to indicate that detention basins designed for pure drainage control purposes may not be very effective in terms of water quality constituent concentration reductions. Although NURP projects are investigating a number of these aspects, the data that would allow us to make more definitive statements are not available at this time.

Street Sweeping.
As in the case of detention basins, the measure of street sweeping effectiveness used is the reduction in urban runoff constituent concentration observed when streets are being swept (or swept at an increased frequency, etc.) as opposed to unswept (or swept at a lesser frequency, etc.). Measures of pounds of pollutant removed as determined by sampling and weighing sweeper hoppers and other such indirect determinations are considered to be of lesser value than actual water quality measurements. Unfortunately, the pilot data base has no synoptic data that can be reliably used at this time (certain seasons are missing in longitudinal designs, test and control site calibration data are unavailable, etc.). As an example, available lead data for the Winston-Salem NURP project are summarized in Table 5-13.

TABLE 5-12. PERCENT REMOVAL EFFECTIVENESS FOR POOLED DETENTION BASIN DATA

		N	Mean	Median	10 Percent	90 Percent
	National	704	83	60	26	163
COD	Influent	136	80	54	19	166
(Mg/l)	Effluent	19*	130	63	20	449
	% Reduction		*	*	*	*
	National	783	168	81	18	332
TSS	Influent	156	170	73	17	565
(Mg/l)	Effluent	50	74	31	6	260
	% Reduction		56%	58%	65%	54%
	National	730	.36	.25	.09	.76
TP	Influent	152	.36	.25	.10	.72
(Mg/l)	Effluent	47	.27	.18	.07	.71
	% Reduction		25%	28%	30%	0%
	National	658	.28	.16	.05	.60
Pb	Influent	86	.26	.07	.006	.43
(Mg/l)	Effluent	45	.21	.06	.002	.24
	% Reduction		19%	14%	67%	44%
	National	276	.052	.036	.015	.100
Cu	Influent	68	.041	.028	.012	.090
(Mg/l)	Effluent	36	.024	.016	.003	.036
	% Reduction		41%	43%	75%	60%

* The N for effluent COD measurements is too small to allow percent reduction to be calculated.

TABLE 5-13. SUMMARY OF LEAD STATISTICS FOR WINSTON-SALEM NURP PROJECT

SITE	CBD		RESID.	
Condition	SWEPT	UNSWEPT	SWEPT	UNSWEPT
Mean Conc. (mg/l)	0.595	0.334	0.164	0.239
Median Conc. (mg/l)	0.437	0.203	0.123	0.161
COV	0.93	1.31	0.89	1.10
N	7	10	11	4
Mean load (lbs)	1.92	0.788	3.92	2.46
Median load (lbs)	0.65	0.57	0.45	0.37
COV	1.76	0.97	8.62	6.52
N	7	9	10	4

Some of the problems first mentioned become clear by examination of the N values in Table 5-13. All are too small, but the four measurements made in the residential basin are totally inadequate to represent this condition. The project design is to sweep one basin daily for three months while the other is totally unswept, and then to switch. At one point in time one basin will be swept for six consecutive months so that, over a two year period, each season will be represented for each basin under swept and unswept conditions. Not reflected directly in Table 5-13 is the fact that the data only represent a fraction of this design and that large seasonal differences exist. At first glance it will appear that street sweeping increases both the runoff concentration and the loads in the Central Business District (CBD) basin. When the total data set is available this may not prove to be the case. On the other hand, the residential basin appears to receive a reduction in event mean concentration when swept but an increase in loads (total pounds) delivered to the receiving water. This apparent inconsistency may be partially explained by the lack of representation of seasonal effects but may be largely due to the very limited number of measurements during the unswept condition. There is no real trend in the variability of the data as expressed by the coefficient of variation (COV) except that it is large, extremely so for loads in the residential basin. About the only thing that can be said at this point in time is that there is no indication that street sweeping is providing a reduction in urban runoff lead concentrations or loads in Winston-Salem. As is noted in Appendix E, a similar observation is made by four of the five NURP street sweeping projects with sufficient data for them to draw a conclusion. What appears to be the case in that, if any water quality benefit is derived from street sweeping, it is masked by the variability of the data and therefore is of little real value.

As in the case of detention basins, a SAS UNIVARIATE run was made for the NURP street sweeping projects data pooled nationwide. The results, presented in Table 5-14, serve more to illustrate the uncertainty regarding water quality improvements attributable to street sweeping than to make a definitative statement. About all that can be said at this time is that street sweeping does not appear to be a BMP that will be universally effective in reducing water quality problems due to urban runoff.

TABLE 5-14. PERCENT REMOVAL EFFECTIVENESS FOR POOLED STREET SWEEPING DATA

SITE	COD	TSS	TP	Pb	Cu
NCQ 248500	(24)	65	48	64	40
WA 208 BELL 0588	(2)	(32)	(17)	(57)	-
WI 413630	(26)	(23)	(94)	(21)	-
WI 413632	18	3	11	(27)	-
WI 413634	(10)	25	41	20	-
WI 413637	(124)	(1297)	(179)	(200)	-

Other Controls.

NURP projects are examining a number of other BMPs, such as recharge basin energy dissipators, undercut ditches, grassed swales vs curb and gutter, catchbasin cleaning, vegetative filters, wetlands, and others to see what water quality improvements in urban runoff might occur, but the data to allow their evaluation are not available at this time.

PROJECT FINDINGS

Seventeen of the twenty-eight NURP projects are sufficiently far along that they have made some preliminary findings. These are presented in Appendix E and briefly summarized below as they relate to urban runoff loads, receiving water impacts, and effectiveness of controls. First, however, the urban runoff problem types (Type I - impairment or denial of attainable beneficial use; Type II - violation of existing water quality criteria; Type III - public concern) as perceived by the projects will be summarized. Only one project reports a type I problem, shellfish bed closings in this instance. Fifteen projects report type II problems, and none reported a type III problem. One project could not specifically identify any type problems.

Loads.

A number of specific pollutants have been identified by the projects relating to the problems they individually found. Eight indicated that heavy metals violated existing water quality criteria. The six heavy metals most commonly cited are lead (5 projects), copper (3 projects), and zinc, mercury, iron, and cadmium (2 projects each). Four projects stated that suspended solids created problems but were not specific. Six projects noted coliform violations. Two projects reported that dissolved oxygen criteria were being violated due to urban runoff; one identifying BOD and COD, while the other cited only BOD loading as the cause. Five projects identified nutrients, and three projects with lakes among their receiving waters of concern reported eutrophication problems. One project reported finding asbestos, but they were the only one to look for it.

Receiving Water Impacts.

Several projects have reported biological data related to their receiving waters. One found that although the chemical effects of urban runoff had little impact on their fish species of interest, its physical effects (especially sedimentation and high flow rates) were damaging and a threat to species propagation. One project reported that, despite the presence of toxic levels of lead, copper, and zinc in their lake of interest, surveys showed that fish (goldfish, carp, and bass) were present. Another project believed, based on receiving water data from their river, that a certain species of fish could not possibly survive, yet a subsequent survey disclosed that it was indeed present. One project reported that the impact of urban runoff on its receiving water, which is used as a drinking water supply, was sufficient to increase treatment costs, but only slightly.

Control Effectiveness.

At this time projects have conducted preliminary evaluations of eight detention basins, six street sweeping efforts, one recharge basin, and one wetland. Four of the detention basins are reported effective, with two reporting lead and copper reductions in the 85-90 percent range, and the other noting a general reduction of pollutant levels, especially TSS. However, in no case were water quality criteria violations eliminated. The remaining four detention basins either were ineffective or lacked enough data to allow a reliable determination of performance to be made.

Only one of the six street sweeping projects reported that loads were reduced as a result of increased street sweeping, and that one noted an improvement in receiving water quality. Another noted some load reductions, but this was not reflected in their water quality data, any effect being masked by the data variability. Three other projects could find no water quality benefit from increased street sweeping due, again, to high data variability. One project lacks sufficient data to make any determination.

The project that examined recharge basins found that they were extremely effective in reducing urban runoff pollution and that such a practice posed no threat to groundwater. This finding is especially significant and may begin to point the way to more widespread use of this type of control measure, including such variants as open bottom catch basins, perforated drains, and other configurations that NURP projects are examining at this time. Data on the effectiveness of wetlands are not adequate to allow performance to be assessed as yet.

CHAPTER 6
CONCLUSIONS

It must be stressed that this is a preliminary report. A final NURP report will be published in 1983. The conclusions that follow are based on data acquired between initial program start-up in 1978 through mid-1981 and analyses performed on those data by both individual NURP projects and EPA.

At this stage, data acquisition is incomplete; most of the individual projects still have active monitoring programs. Analysis and interpretation of data is even less complete, due to the inherent time lag required for laboratory analysis and entry into the data management system.

Partial data analysis has been accomplished, and preliminary conclusions have been drawn in some of the objective areas - both at the local level and the national scale. In addition, certain screening analyses have been performed making use of such data as are now available. These analyses provide a useful start to an assessment of the significance of urban runoff as a contributor to water quality problems.

While some of the preliminary (national scale) conclusions which are presented below are believed to be sound, analyses were performed more to illustrate approaches and procedures than to suggest actual results, and these analyses are so identified. Lack of data at this time has precluded many important areas from even being addressed as yet.

Even for those analytical conclusions which are thought to be sound, the limited data base on which they were based does not warrant suggesting that they are all scientifically substantiated at this time.

A number of local projects have drawn tentative conclusions on a variety of aspects related to the overall objectives. All are useful and informative, and thought likely to hold up under further analysis, but like the national scale activities, are based on incomplete data and have not been reviewed thoroughly enough to suggest that they are all scientifically substantiated.

NURP fully expects that the important conclusions which will ultimately be drawn at both local and national levels will be scientifically defensible. NURP is not there yet, as a careful reading of the preliminary report will confirm.

Consistent with the structure of the overall report, conclusions are organized in accordance with the three basic categories of loads, water quality effects, and controls.

Loads.

1. Due to the highly variable nature of urban runoff, a large data base significantly improves the confidence in any conclusions drawn. NURP's emphasis on data acquisition has, even at this interim stage, produced a data base which significantly exceeds the total pool of data on urban runoff available from other sources. Comparisons have been made with other sources which extend the utility of the NURP data base.

2. Urban runoff event mean concentrations of five pollutants analyzed to date have been demonstrated to have underlying probability distributions which are log normal. The statistical parameters (mean and coefficient of variation) have been determined for COD, suspended solids, total phosphorus, lead, and copper. Using the statistical properties of the fundamental probability distribution, it is possible to do the following:

   (a) Define urban storm runoff concentrations in a concise way, and facilitate comparisons with other sources of data.

   (b) Separate the "random" components of the variability in examining whether there are real, significant differences in urban runoff quality based on location, land use, or any of the other factors which have been suggested in the past to influence runoff quality.

   (c) Make statements concerning the frequency with which concentrations of any particular magnitude will occur.

   (d) Interpret data from other sources which report ranges, and apply an improved perspective to such information.

   (e) Examine water quality impacts and evaluate such effects in terms of potential for significant threats to beneficial uses.

3. It will be possible, when additional data have been analyzed, to develop quantitative expressions which will express differences in urban runoff quality as a function of factors such as land use, geographical location, season of the year, etc. The procedure adopted (examining subpopulations) appears to provide a viable technique for so doing. Indications of regional, seasonal, and land use effects presented in Chapter 5, should be considered tentative, because the data base for performing such comparisons is still sparse. NURP expects, however, that some of the differences suggested will be confirmed.

For example, Denver and other locations with similar geography will, because of climate and soil characteristics, continue to exhibit higher concentrations of suspended solids and other contaminants closely associated with them.

4. About one-half of the substances on EPA's priority pollutant list sometimes occur in urban runoff. Heavy metals (especially lead, zinc, and copper) are much more prevalent than organic priority pollutants. Some of the metals are present often enough and in high enough concentrations as to be considered threats to beneficial uses.

5. Organic priority pollutants appear to be generally present only in certain urban runoff discharges. Where present, and the beneficial use is potable water supply, there is a significant concern. Stream dilution and other mitigating factors may prevent any real problem, but communities with water supply intakes in close proximity to urban runoff discharges are encouraged to check for the relatively limited number of pertinent priority pollutants which have been detected in urban runoff.

6. Total suspended solids concentrations in urban runoff from available NURP data appear to be lower in general than suggested by other studies.

Water Quality Effects.
Conclusions on the receiving water impacts of urban runoff will be presented for each designated beneficial use for which it is believed that urban runoff will have a negative effect on water quality sufficient to cause impairment or denial of the use.

Fresh water aquatic life.

1. The effect of oxygen demanding substances in urban runoff on dissolved oxygen levels in receiving water has not been examined yet. This analysis will be done when sufficient data become available.

2. The potential for suspended solids to have a significant deleterious effect has not yet been assessed. This analysis will be done when sufficient data are available.

3. Organic priority pollutants do not appear to pose a general threat to fresh water aquatic life. This is based upon the limited available data on the frequency with which they are found in urban runoff discharges and the measured end of pipe concentrations relative to proposed toxic criteria.

4. At this time heavy metals appear to be the urban runoff contaminants that have the greatest potential for impacts on the

aquatic life beneficial use. This conclusion is based on the fact that a number of heavy metals are consistently found in urban runoff in high concentrations relative to suggested toxic limits.

5. It appears reasonable at this time to conclude that some degree of impairment of this benefical use is probably common in many water bodies which receive urban runoff. With some exceptions, however, the degree of any impairment that exists does not appear to be of sufficient magnitude to generate serious local concern. This conclusion is based on the following:

    - The screening analysis suggests that local conditions can be expected where the magnitude and frequency of intermittent concentrations of some metals would have adverse effects; conversely, there will be local conditions where adverse effects are very unlikely or extremely rare occurrences. The governing local circumstances are storm flow characteristics and average rainfall intensity, both of which vary with geographic locality.

    - Absence of evidence from NURP projects confirming impairment of this beneficial use which is considered significant at the local level. Bellevue, Washington with a high degree of local awareness and interest in protecting a fishery, has concluded that chemical constituents in urban runoff create no problem for their sport fishery. Glen Ellyn (NIPC) documents high metals concentrations which undoubtedly strongly influence the nature of the fishery which is present, but local opinion does not characterize this as a problem, i.e., they do not consider the degree of use impairment to be significant.

    - In an EPA examination of over 10,000 fish kills that occurred from 1970 to 1979, only 265 were attributed to runoff of any kind, and less than one-half of that number were associated with urban runoff.

6. Indications to date do not provide any basis for believing that a denial of this benefical use is a widespread, general occurrence.

Marine aquatic Life.

1. Adverse effects of urban runoff in marine waters will be a highly specific local situation. It is not a beneficial use generally threatened by urban runoff, though specific instances where it is impaired or denied can be of significant local and even regional importance.

2. A significant impact of urban runoff on shellfish harvesting has been well documented by the Long Island, New York NURP project.

3. Coliform organisms present in urban runoff are the primary pollutant indicator of concern.

Recreation.

1. Pollutants in urban runoff which pose the most significant threat to this beneficial use are pathogenic organisms (as possibly indicated by the presence of coliform bacteria), nutrients (particularly phosphorus), and suspended solids.

2. Coliform bacteria are present at high levels in urban runoff and affect all types of water bodies -- streams, lakes, bays, estuaries, and oceans. Whether the potential for use impairment is realized depends principally upon physical factors such as the location of the discharge relative to swimming areas and the degree of dilution and dispersal. In this sense, actual use impairment will be a local condition. This problem has been identified by a number of projects; however, data are not yet available for characterizing the extent and severity of use impairment.

3. Water bodies particularly susceptible to recreational use impairment by nutrients are lakes. In the cases where at least some information is presently available (Lake Quinsigamond, Irondequoit Bay, Lake Austin, Lake George) it is apparent that the degree of beneficial use impairment varies widely, as does the significance of the urban runoff contribution. Detailed analysis which will permit establishing the relative significance of urban runoff compared with other sources is not available at this time except for Lake Quinsigamond, but can be expected to be very site specific. At Lake Quinsigamond urban runoff was found to be a significant source of the critical nutrient phosphorus, such that a proposed water quality management plan will include the objective of reducing urban runoff loads. By contrast, very preliminary indications are that nutrients in urban runoff are not causing any appreciable negative impact on Lake Austin and controls do not appear warranted, pending results of analysis of long term effects.

4. Adverse impacts on recreational use caused by suspended solids have not yet been evaluated.

Public water supply.

1. Ground water aquifers do not appear to be threatened by pollutants in urban runoff caused to percolate through the ground. This finding is based on only one NURP project (Long Island) which has specifically examined this issue and must be considered in that light.

2. Lakes and impoundments that receive urban runoff and also serve as water supply sources are being addressed in NURP, but at this time results available are too limited to warrant drawing preliminary conclusions of a general nature.

3. Rivers or streams which serve directly as water supply sources with intakes in close proximity to urban runoff discharges are probably rare nationwide, but some do exist. From information and preliminary analysis developed to date, it is inferred that, where water supply intakes are in close proximity to urban runoff discharges, a serious enough potential for adverse impacts exists that careful examination of the situation is prudent. The principal contaminants of concern suggested by preliminary results include heavy metals, a limited number of the organic priority pollutants, and coliform bacteria. Although potential for a problem is present, there are mitigating factors which reduce the likelihood that a problem situation will actually exist at any given location. The present status of our analysis does not warrant any firm conclusions to be drawn with regard to the prevalence of actual problem situations of this type. However, based on the fact that local factors can significantly reduce the potential, and the belief that relatively few water supply intakes exist at stream locations dominated by urban runoff, NURP believes that any problems that do exist will be limited rather than widespread occurrences.

Control effectiveness.

1. Some detention basins are quite effective at reducing pollutant concentrations in urban runoff, with reductions on the order of 90 percent or better reported. High removals of suspended solids and heavy metals, especially copper, are noted, with somewhat lower removal efficiences for phosphorus and chemical oxygen demand.

2. Other NURP project detention basins do not appear to be performing very well in terms of reducing effluent concentrations and may not be capable of providing a significant water quality improvement. The performance of some is quite variable, being fairly good for some storm events (~ 50 percent reduction) and quite poor for others. Some detention basins are consistently poor performers.

3. The design features of detention basins play a very important role in their performance in terms of reducing pollutant concentrations. Data suggest that basins designed to merely control water quantity (drainage) problems may not function well in water quality terms. The installation of an arbitary detention basin could even exacerbate water quality problems. As more NURP project data become available, it will be possible to make definitive recommendations on detention basin design for water quality improvement.

4. Street sweeping is effective for its original purpose, but it does not appear to be universally effective in reducing urban runoff pollution. Only one project out of six has been able to show any water quality improvement as a result of even very intensive (daily) street sweeping.

5. The effectiveness of street sweeping as a water quality BMP should be measured in terms of actual pollutant reduction in the runoff, not determined theoretically from estimates of pounds removed from street surfaces obtained from examination of street sweeper hopper contents, pounds remaining on the street surface, etc.

6. Data are insufficient to allow firm projections to be made as to those conditions under which street sweeping might be able to provide a water quality improvement, but preliminary indications are that it might be limited to semi-arid parts of the country with pronounced wet and dry seasons.

7. Data indicate that under certain conditions street sweeping may actually increase urban runoff pollutant levels, but this conclusion must be considered highly speculative until more data become available. A possible mechanism is that sweeping can break up larger particles making them available for washoff by smaller, less intense storms with less runoff volume for dilution. At its conclusion NURP will be able to make definitive statements in this regard.

8. Recharge Basins appear to offer promise as effective and economical BMP's for reducing urban runoff pollution to surface waters, without creating a threat of adverse impact on ground waters. This conclusion is tentative, and is based on preliminary data from monitoring efforts on one device, and screening analyses to examine applicability. Applicability can be expected to vary on the basis of site-specific conditions such as soil percolation rates, depth to water table, topography, proximity to water supply wells, and the like. Preliminary indications are, however, that recharge basins could have relatively broad applicability.

GENERAL DISCUSSION

In summary, the possibility of having water quality problems caused by urban runoff varies in type and degree. Whether or not a problem may truly exist is strongly influenced by a variety of local, site-specific characteristics. These include:

- Local climatology and hydrology;
- Type of water body which is the principal recipient of urban runoff;

- The particular beneficial use desired; and
- Local attitudes, resources, values -- especially values as applied specifically to individual water bodies in an area.

The NURP screening analysis to date suggests that there are a lot of places where urban runoff is unlikely to result in problems (quantifiable problems reflected in standards violations or use impairment). The same screening analysis also suggests that there should be a significant number of locations where urban runoff could theoretically result in the occurrence of a quantifiable problem. Some "possibilities of problem situations" would have to be discounted on the basis of the actual beneficial uses. For example, "problems" based on drinking water standards not being met would be problems only if the receiving water is actually used as a drinking water source. Local attitudes or alternatives could further reduce a theoretical or potential problem to the category of no problem from a practical standpoint.

NURP is unable, at this time, to estimate the probable relative distribution of sites in the nation which fall into the above alternate categories. Our analysis efforts are continuing to try to make this determination. At this time, however, NURP is not highly optimistic about its ability to be able to make a credible generalization of this type. However, some rather sweeping generalizations that will be true more often than not are offered. The water quality impact of urban runoff will be greatest in small urban impoundments, especially those with no other influent flows. Aside from possible near-shore effects, the water quality impact of urban runoff will diminish with impoundment size and, consequently, so should the potential for occurrence of water quality problems. Similarly, the water quality impacts of urban runoff will be greatest in small streams, especially those that headwater in the urban area. As stream flow and size increase, the potential for water quality impacts caused by urban runoff should decrease as should problem potential. Furthermore, in this regard, swiftly flowing streams should be less vulnerable than more sluggish ones. Bays and estuaries are so complex that even such rather simplistic generalizations as the foregoing are difficult to justify, and the same is true of the near-coastal oceans.

There are plateau and threshold effects for many pollutants that influence their impact on a given receiving water and, consequently, the strategy for their control. As an example, consider the case where the level of a toxic substance is four times the LC-50 value for a species of fish associated with the desired beneficial use. If urban runoff is the only source of the toxicant, and if the implementation of a given control measure results in a 50 percent reduction in loads, the money spent would have been wasted insofar as attainment of the designed beneficial use is concerned. To be sure, pounds of pollutants would have been removed at a (perhaps) cost-effective rate of so many dollars per pound, but there would still be none of the sought-after fish in the water and, consequently, the desired beneficial use would still be denied. Similarly, the removal of a contaminant that is at such low levels that it is not interfering with a designated beneficial use, simply because the substance is present in urban runoff, results in the incurrence of costs but produces no benefit because the beneficial use was not being impaired in the first place.

While the tools are available for conducting cost-effectiveness analyses and the procedures are rather straightforward, NURP is not so fortunate in the area of benefit-cost analysis. Damage theory and utility cost tools exist, but their application is far from straightforward and is subjective at best. The Agency is currently attempting to remedy this situation and, successful approaches, if found, they will be applied by NURP.

Because of the local nature of water quality problems in terms of existence and cause and because in many cases much more attractive approaches than control of urban runoff will be available for addressing problems where they are found to truly exist, it does not appear desirable to adopt a universal requirement for urban runoff control or treatment.

Urban runoff does appear to contribute significantly to certain water quality problems in certain areas (there are a number of well-documented cases in the NURP program), and there are situations where control of urban runoff is the only realistic action that is available to address the problem. However, the practicality of being able to solve some problems will be constrained in some cases by technological limitations, in some cases by costs, and in some cases by physical site constraints. Some examples of such constraints include:

> Technological. Situations which require very high degrees of removal of a pollutant may prove to be beyond the performance capabilities of control measures available. Example: Suspended forms of a contaminant lend themselves to removal whereas, if the soluble component is a substantial fraction of the total, control measures may not be able to reduce the total load sufficiently to achieve desired effects.
>
> Cost. The cost associated with reducing the overall load of a pollutant from an entire urban area could prove to be prohibitive, even though relatively cost effective when applied in restricted areas. Usually, the overall urban runoff load must be addressed if the "problem" is to be successfully attacked. However, it may provide real benefit to apply efficient, cost effective controls serving only limited areas where it can be done conveniently.
>
> Physical Site Constraints. Even where efficient, cost-effective controls may be available for reduction of the specific pollutants contributing to a particular problem, the physical space to implement them may not be obtainable. For example, Central Business Districts may be a significant pollutant source, but provide little opportunity for control.

CHAPTER 7
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